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BEFORE THE
UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY

IN RE APPLICATION FOR A FUEL ADDITIVE WAIVER FILED BY ETHYL CORPORATION UNDER § 211(f)(4) OF THE CLEAN AIR ACT

RECEIVED
JUL 12 1991
EPA AIR DOCKET

Submitted by:

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July 12, 1991

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Systems Applications International

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A Division of Clement International Corporation
Environmental and Health Sciences

MEMORANDUM

TO: Ethyl Corporation

FROM: Ralph L. Roberson, P.E. Ralph L. Roberson

DATE: May 1, 1991

SUBJECT: Analysis of EPA Manganese Emission Testing Data

The purpose of this memorandum is to summarize the results of manganese emission testing conducted by EPA's Ann Arbor Laboratory.[1] Details of EPA's test program are provided in the above-referenced memorandum. EPA tested a total of 15 vehicles. All emission tests followed the same sequence in that three different driving cycles were examined. Emission tests for the three driving cycles : (1) Federal Test Procedure (FTP), (2) highway cycle (HWY), and (3) New York City Cycle (NYCC) were always conducted in the same order. All manganese emission test results are presented as a percent of input manganese emitted.

Some vehicles were tested as many as four times (ID-8888), while other vehicles were tested only once (e.g., (ID-0015). Therefore, the first step of our analysis is to compute arithmetic average manganese emissions for each driving cycle for each vehicle. We compute vehicle averages so that we can weight each individual vehicle equally when computing overall fleet averages. Table 1 summarizes average percent of input manganese emitted for each vehicle and for each driving cycle. Table 1 also shows

[1] EPA Memorandum -- MMT Testing Program Report from J. Bruce Kolowich, Fuels and Chemistry Services to Mary T. Smith, Field Operations and Support Division, dated October 29, 1990.

the number of individual tests used to compute the average for each driving cycle and for each vehicle.

Next, we compute a fleet average for the percent of input manganese emitted for each driving cycle. Again, individual tests for each vehicle are averaged so that each vehicle is weighted equally in the fleet averages. Lastly, we tabulate maximum and minimum manganese emissions; these values are based on individual vehicle averages.

Driving	Percent Input Manganese Emitted		
Cycle	Average	Minimum	Maximum
FTP	14.0	5.6	33.7
HWY	6.6	4.2	9.8
NYCC	16.9	9.7	26.3
Combined	12.5	--	--

TABLE 1. SUMMARY OF EPA MANGANESE EMISSION TEST DATA.

Car ID/ Test Cycle	Percent Manganese Emitted	Number of Tests
8888		
FTP	14.0	4
HWY	9.1	4
NYCC	20.3	4
0099		
FTP	15.0	4
HWY	9.8	4
NYCC	17.8	4
0011		
FTP	9.6	2
HWY	9.0	3
NYCC	23.1	3
0021		
FTP	33.7	4
HWY	4.8	4
NYCC	26.3	3
0031		
FTP	11.2	2
HWY	4.2	2
NYCC	18.5	2
0077		
FTP	10.5	2
HWY	6.6	2
NYCC	13.3	2
0024		
FTP	5.6	1
HWY	5.5	1
NYCC	18.7	1
0041		
FTP	7.4	2
HWY	5.5	2
NYCC	14.9	2

TABLE 1. SUMMARY OF EPA MANGANESE EMISSION TEST DATA (Continued).

Car ID/ Test Cycle	Percent Manganese Emitted	Number of Tests
0051		
FTP	12.0	4
HWY	7.2	4
NYCC	14.5	4
0016		
FTP	19.0	1
HWY	5.6	1
NYCC	13.0	1
0018		
FTP	19.0	2
HWY	6.2	2
NYCC	13.1	2
0020		
FTP	11.0	2
HWY	5.6	2
NYCC	9.7	3

AN EMISSION STUDY OF HiTEC 3000® PERFORMANCE ADDITIVE: THE MANGANESE BALANCE PROJECT

I. SUMMARY

One issue that has arisen in connection with Ethyl Corporation's ("Ethyl") efforts to gain approval for use of its HiTEC® 3000 Performance Additive ("the Additive") in unleaded gasoline in the U.S. is how much manganese will be emitted from the tailpipe of vehicles using fuel containing the Additive. To address this issue, Ethyl initiated a study desgned to determine the ultimate deposition of the manganese present in the fuel consumed by test vehicles. The results of the study, which was jointly conducted by Ethyl and Southwest Research Institute ("SwRI") in San Antonio, Texas indicate that, based on a driving cycle designed to <u>maximize</u> manganese tailpipe emissions, about 27 percent of the manganese in the fuel is emitted from the tailpipe, of which an estimated 7 to 10 percent is too large to remain airborne. The remainder of the manganese remains in the internal systems of the automobile. By way of comparison, airborne manganese emissions based on driving cycles better reflecting <u>typical</u> driving conditions are substantially less, in the 10 to 20 percent range, as measured in particulate testing conducted by SwRI. See Appendix 5 to Ethyl's most recent waiver application.

An attempt was made in the study to separate particles emitted from the tailpipe into coarse (greater than 5.0 micron) and fine particles using a special trapping mechanism. Ethyl designed the trapping system so as to separate from the fine particles all coarse particles large enough to settle out quickly from the atmosphere. Of the 26 to 28 percent manganese emitted from the tailpipe as reflected in the results of the study, the trapping mechanism separated 3 percent as coarse particles and 23 to 25 percent as fine particles. However, due to limitations of the trapping mechanism for coarse particles, it is probable that some of the material trapped as fine particles are actually coarse particles. This means that the fine particle component reflected in the test results may be higher than would occur under actual, "real world" operating conditions, as reflected in SwRI test results mentioned above.

Ethyl installed particulate trapping devices onto the tailpipes of three 1991 Chevrolet S-10 pickup trucks. The trucks were sent to SwRI where they underwent a mileage accumulation program using a prescribed driving cycle that represented about 32 percent city driving and 68 percent highway driving. The driving cycle included five wide-open throttle sequences per 400 miles designed to loosen any deposits that might form in the exhaust system. The trucks accumulated 20,000 miles and then all exhaust components and the trapping mechanisms were removed and analyzed for manganese content. In addition, one engine from one truck was dismantled and various engine components were analyzed for

manganese. The total manganese found in this one truck represented 94 percent of the total manganese consumed in the gasoline.

II. METHODOLOGY

Ethyl decided to conduct a mileage accumulation program on vehicles equipped with mechanisms to trap all particulate after it leaves the tailpipe. Three 1991 Chevrolet S-10 pickups, equipped with a 4.3L V-6 engine and a camper shell, were purchased. Pickups were selected so that there would be sufficient room to house the trapping mechanism while the camper shell would protect the trapping mechanism from the elements.

A. Trapping Mechanism

The mechanism used to trap all particulate leaving the tailpipe was designed to separate coarse particles (greater than 5 micron) from the fine particles (less than 5 micron). The system used to trap the coarse particles was a 3" anchored vortex/cyclone separator. A scaled drawing and a sketch of the cyclone separator assembly are shown in Attachments 1 and 2. Ethyl had three units built by ECS/Roush, Inc. of Livonia, Michigan. These units were then installed directly behind the tailpipe on each truck so as not to alter the normal exhaust configuration for the test vehicles.

The system used to accumulate fine particulate was a 12" diameter absolute filter manufactured by Donaldson Company, Inc. This filter has a 99.9% efficiency rating for 0.3 micron particles. Three stainless steel units to house the filters were constructed and installed behind the anchored vortex/cyclone separators on each truck.

The complete trapping system as installed in the truck is shown in Figure 3 of Attachment 3.

B. Mileage Accumulation

The mileage accumulation program was conducted by SwRI. Complete details of all work performed by SwRI in support of this project are provided in Attachment 3. The specific mileage accumulation program consisted of approximately 68 percent highway driving at speeds of 55-65 mph and 32 percent AMA city-suburban driving at speeds of 30-55 mph. Approximately 400 miles were accumulated on each vehicle per 10-hour shift. Electronic tachographs were installed in each truck to monitor highway durability operations. A schedule of the mileage accumulation route is shown in Appendix C of Attachment 3.

The base fuel used in the mileage accumulation program was Howell EEE. For the first 1,000 miles, the trucks accumulated mileage on Howell EEE gasoline with no additive. Thereafter, the trucks were operated with Howell EEE gasoline plus 0.031 grams Mn/gallon as HiTEC 3000 Performance Additive. The extent of the mileage accumulation program was 20,000 miles.

Motor oil used was Quaker State 10W-30. Oil changes were done after 1,000, 9,000, 15,700 and 20,000 miles. All used-oil and oil filters were sent to Ethyl's research facility in Baton Rouge for later analysis.

C. Emission Tests

Gaseous and particulate emission tests were conducted by SwRI on each truck after 1,000, 5,000, 10,000, 15,000 and 20,000 miles. The purpose of this testing was to make certain that the trapping and emission systems on each truck were still operating satisfactorily. At 1,000 miles, two emission tests were conducted with "clear" Howell EEE gasoline and one test was made with Howell EEE containing HiTEC 3000. All subsequent tests were conducted with Howell EEE containing HiTEC 3000. For truck CP2, the 1,000 mile emission test results showed unusually high HC and CO emissions. An investigation of the cause indicated a faulty oxygen sensor and it was replaced. No other changes were made to the emission control system components of the trucks for the duration of the mileage accumulation program. The results of the emission testing for the program are given in Table 1 of Attachment 3, and show that, throughout the mileage accumulation program, the emission control systems of the test vehicles operated in a stable manner.

Particulate emissions were measured, during the course of the test program, at two different sampling probes in the SwRI particulate testing tunnel described in Appendix 5 of Ethyl's most recent waiver application. The particulate emission results, also shown in Table 1 of Attachment 3 and measured using an FTP test cycle, indicate that the trapping system on each truck was working efficiently throughout the mileage accumulation program. SwRI indicated that they have obtained particulate values like 0.002 gm/mile by just sampling the filtered air flow with no automotive exhaust.

D. End-of-test Program

After the 20,000 mile emission test, the exhaust system from each truck was removed and sent to Ethyl's Analytical Research group in Baton Rouge for manganese determination. Those items removed from each test vehicle included exhaust pipes, muffler, catalytic converter, cyclone separator and Donaldson absolute filter. Special care was taken in the shipment of these components from San Antonio to Baton Rouge to ensure that particulate matter would not fall out or escape. Heavy plastic bags were taped over all openings of the components that were shipped. The components were packed carefully in containers to prevent damage from rough handling during shipment.

Later on in the program, after preliminary manganese analyses of the particulate filters and exhaust components indicated good agreement between the three trucks, Ethyl decided to dismantle one engine and look for more manganese. Truck CP3 was chosen since it used the most manganese in the fuel and the amount of manganese found in the exhaust system was the largest (79.4%). Items removed by SwRI from the engine of CP3 were the exhaust and intake manifolds, spark plugs, EGR valve and deposits from the engine itself. These items were also shipped to Ethyl Analytical Research group in Baton Rouge for analysis.

The samples that were analyzed by the Ethyl Analytical Research group for manganese were prepared by different means. Solutions used to dissolve the various deposits were hydrochloric acid, sulfuric acid, nitric acid, and aqua regia (a solution of nitric acid and hydrochloric acid).

The metal components, (i.e., pipes, muffler, cyclone separator, filter holder, manifolds, catalyst), were cut into small pieces and soaked and rinsed in concentrated hydrochloric acid solution until clean. The catalytic converter bricks and the engine deposits from truck CP3 were rinsed and leached with concentrated hydrochloric acid and then were further soaked in aqua regia until either dissolved or clean.

For sample preparation of the absolute filter, the paper from the filter was removed with care and placed in beaker solutions of first, hydrochloric acid and then aqua regia. This procedure removed the deposits that were on the paper. Next, the paper was leached and totally digested with sulfuric and nitric acid solutions.

The motor oil and oil filters were also leached and totally digested in sulfuric and nitric acid solutions. All sample preparation steps and sample handling were done with extreme care to minimize the chance of losing small amounts of particulate material.

The elemental determinations for manganese were made using an inductively-coupled plasma (ICP) spectrometer with an internal standard calibration technique to maximize precision and accuracy.

E. Manganese Analysis Results

Based on fuel consumption records kept by SwRI during the mileage accumulation and emission testing phase, the amount of manganese consumed in the fuel by each truck was between 25 and 26 grams.

This is a very small amount of manganese to find in the large surface area of the engine and exhaust system of each vehicle.

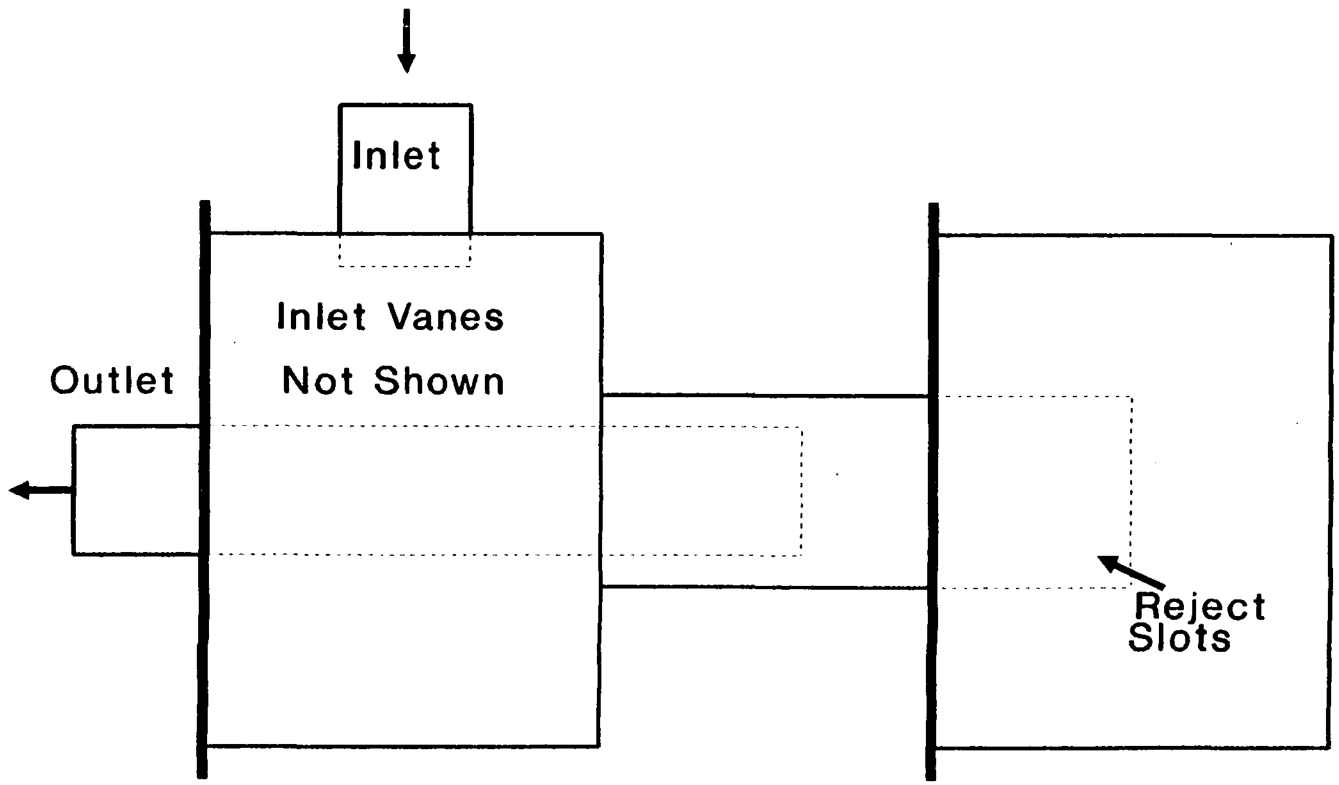
The results of the manganese analysis for each truck are shown in Attachment 4.

The data analysis indicates that between 26 and 28 percent of the manganese consumed in fuel by the trucks is emitted from the tailpipe. Of this total, about 3 percent was found in the cyclone separator (coarse particles), while 23 to 25 percent was found in the absolute filter (fine particles). The amount of manganese emitted from the tailpipe is very consistent from truck to truck and should be a reasonably accurate estimate. The amount in the absolute filter may be a little high due to the limitations of the cyclone to separate all coarse particles. The collection efficiency of the cyclone separator varies with the flow rate through it. The slower the flow, the less efficient it becomes. This unit was designed to separate particles as small as 5 micron at a flow rate of 250 cubic feet per minute. At rates slower than 250 cfm (e.g., engine at idle or at lower speeds of 25 to 45 mph), the cyclone may not separate or collect some of the coarse particles passing through it. By contrast, particulate emission tests conducted by SwRI for Ethyl on other test vehicles indicate that airborne manganese particulate ranges between 10 and 20 percent of manganese consumed in the fuel (See Appendix 5 to the most recent Ethyl waiver application).

The remainder of the manganese particulate remain in the internal components of the automobile. For example, Ethyl's manganese analysis of the three trucks indicate that between 37 and 39 percent of the manganese consumed in the gasoline are found in the exhaust system (tailpipe, muffler, catalytic converter). Another 11 or 12 percent was found in the motor oil and filter.

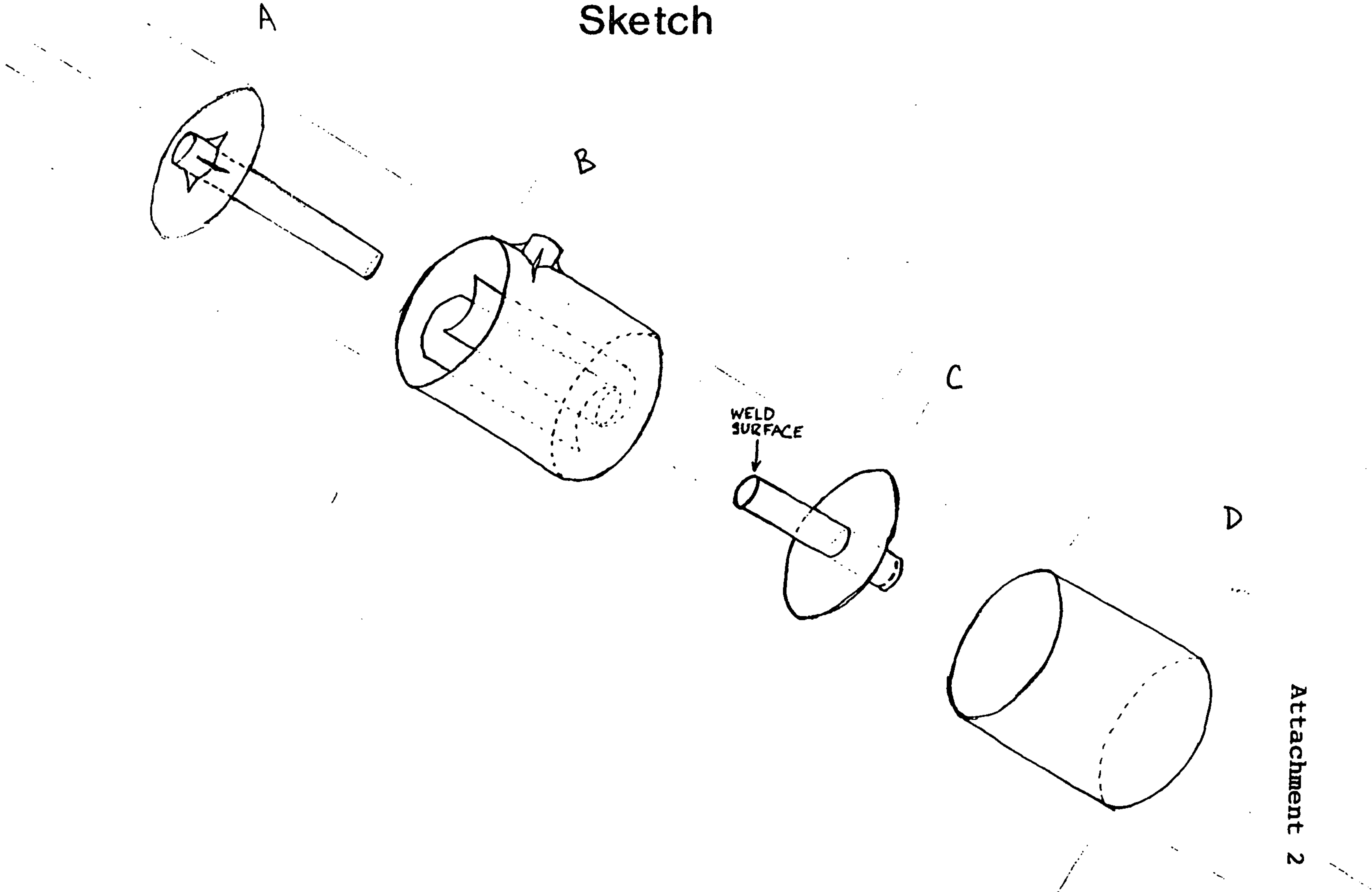
Manganese analysis of the engine components from truck CP3 found an additonal 14.6%. For truck CP3, the detailed analytical analysis was able to account for <u>94%</u> of the manganese consumed in the gasoline. The other 6% can be attributed to loss in handling the individual components and accuracy of instrumentation.

Anchored Vortex/Cyclone Separator Assembly



Attachment 1

Anchored Vortex/Cyclone Separator
Sketch



Attachment 2

Attachment 3

SwRI 08-4070

EMISSION STUDIES USING HiTEC® 3000 ADDITIVE: THE MANGANESE BALANCE PROJECT

By

Charles T. Hare

FINAL REPORT

Prepared for

ETHYL PETROLEUM ADDITIVES DIVISION
20 South 4th Street
St. Louis, Missouri 63102-1886

May 1991

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

SwRI 08-4070

EMISSION STUDIES USING HiTEC® 3000 ADDITIVE; THE MANGANESE BALANCE PROJECT

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FINAL REPORT

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May 1991

Charles T. Hare

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Director, Department of Emissions Research
Automotive Products and Emissions Research
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SOUTHWEST RESEARCH INSTITUTE

6220 CULEBRA ROAD ° POST OFFICE DRAWER 28510 ° SAN ANTONIO, TEXAS, USA 78228-0510 ° (512) 684-5111 ° TELEX 244846

May 10, 1991

TO: Ethyl Petroleum Additives Division
20 South 4th Street
St. Louis, MO 63102-1886

ATTN: Mr. Don P. Hollrah
Product Manager

SUBJECT: Final Report on SwRI Project No. 08-4070, "Emission Studies Using HiTEC® 3000 Additive; the Manganese Balance Project"

I. INTRODUCTION

Initial contact regarding this work was made by Mr. Hollrah on November 12, 1990, in a conversation with Kevin Brunner of SwRI. We responded by letter dated November 13, leading to a November 28 meeting at SwRI attended by Mr. Hollrah, Mr. Lenane, and Mr. Leeper. Ethyl subsequently sent a request for proposal (December 17), and SwRI responded with Proposal 08-11016, dated December 26. Following further discussions, Ethyl requested revisions in project scope on January 10, 1991; and we responded with proposal revisions on January 15. The Ethyl requests of December 17 and January 10 are reproduced as Appendix A for reference. Modifications made in test details as the project proceeded are documented in other sections.

II. PREPARATORY EFFORTS

Acquisition and preparation of test vehicles and on-board equipment was handled by Ethyl and other suppliers, not under this project. SwRI did supply quotations on the vortex separators and filter holders prior to Ethyl's reaching this decision. When the vehicles arrived, SwRI modified the pressure lines leading to cab-mounted exhaust system pressure gauges for greater rigidity, and anchored the separator/filter assemblies to their mounting boards more securely. Figures 1 and 2 show two views of test vehicle CP2 undergoing an FTP emission test on the chassis dynamometer. Figure 3 shows detail of the vortex separator and filter mounted in the truck bed, and Figure 4 shows the particulate sample filter holders and external portions of the probes used in this and concurrent project work for Ethyl Corporation.

Durability/emission test fuel was obtained early in the program, in an amount sufficient for the subject project <u>and</u> several other projects being conducted for Ethyl. An analysis of this "clear" fuel, SwRI Code 1194, is given in Appendix B. Note that the manganese content was analyzed at less than 1 mg/gallon. After blending with the matched amount of HiTEC® 3000 supplied by Mr. Hollrah, the initial sample yielded too low a concentration value. Additional mixing was done, and AA analysis showed 0.031 g/gallon manganese, in agreement with the target value of 0.03125 g/gallon. A sample submitted to Ethyl for analysis gave similar results, so the blended fuel, SwRI Code 1198, was approved.

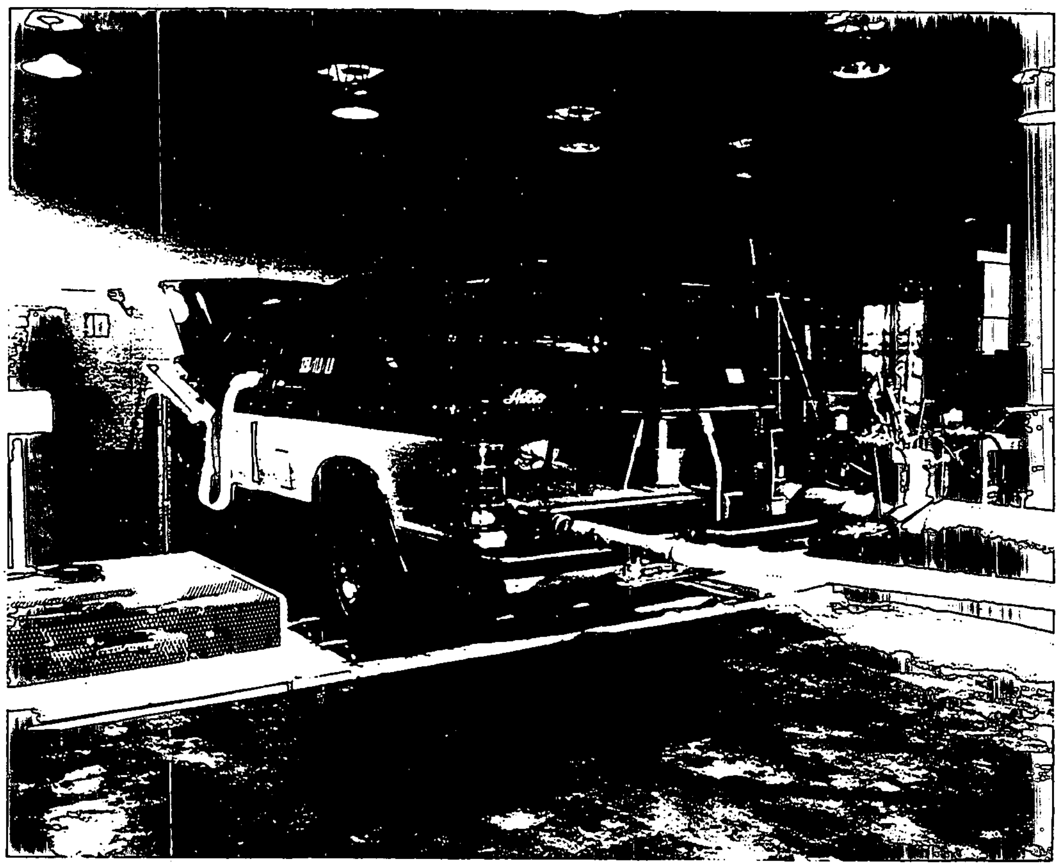


FIGURE 1. REAR QUARTER VIEW OF TEST VEHICLE ON CHASSIS DYNAMOMETER

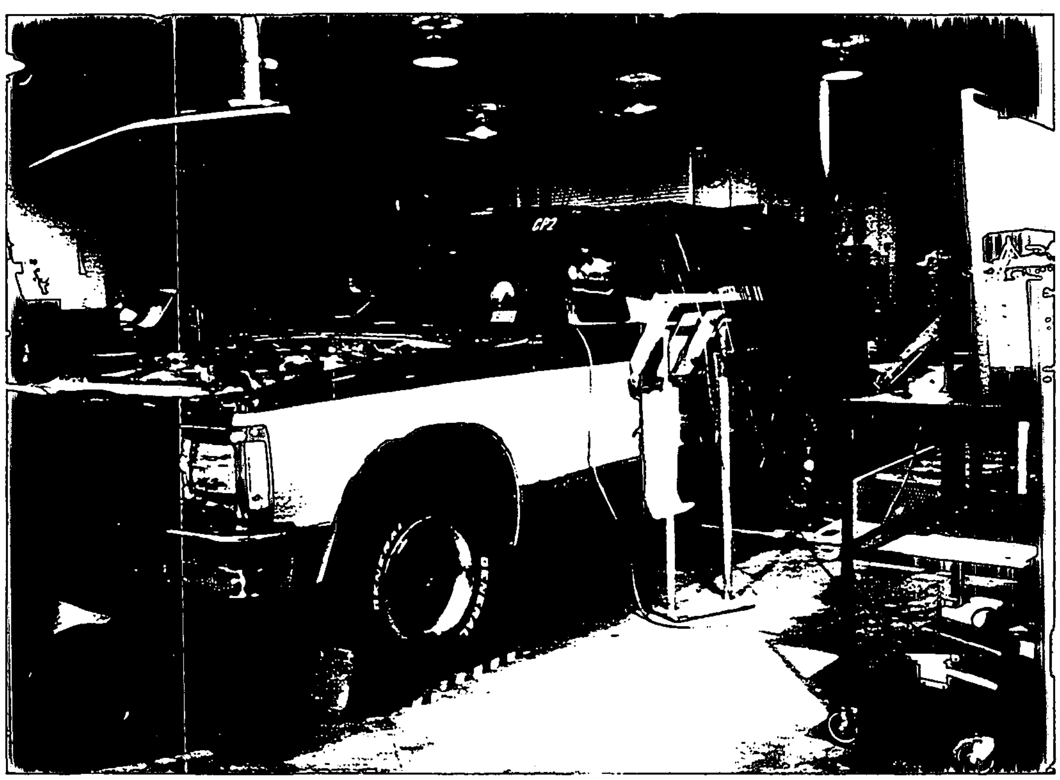


FIGURE 2. FRONT QUARTER VIEW OF TEST VEHICLE ON CHASSIS DYNAMOMETER

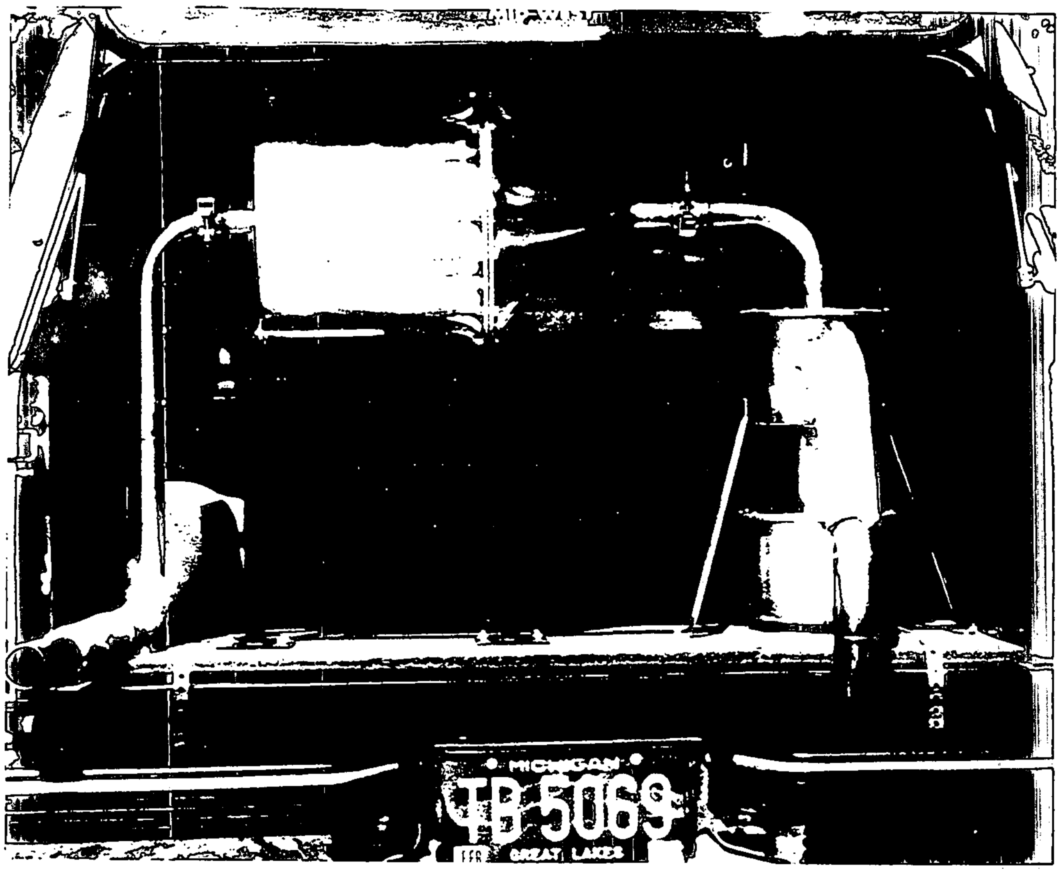


FIGURE 3. DETAILS OF EXHAUST FILTER AND VORTEX SEPARATOR

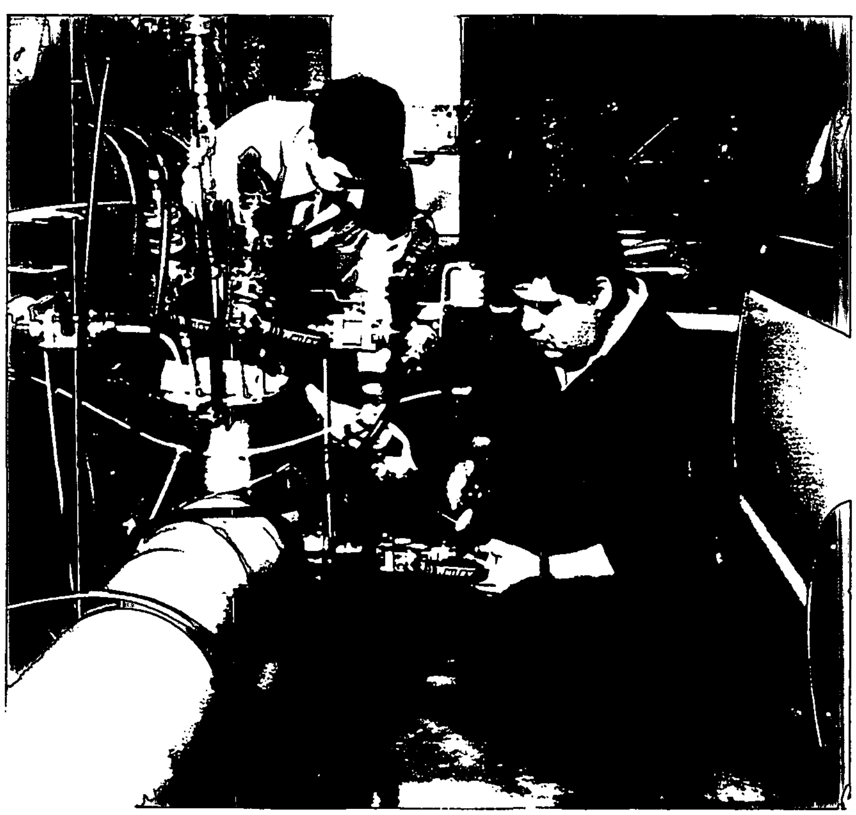


FIGURE 4. TECHNICIANS INSERTING SAMPLE FILTER INTO ONE OF SEVERAL FILTER HOLDERS USED

Several drums of clear fuel (Code 1194) were retained for initial distance accumulation (up to 1000 miles) and emission tests on the three test vehicles. Additional drums were set aside for other Ethyl projects, as required. A single batch of Quaker State 10W-30 lubricating oil was obtained for the test vehicles, and it was found to contain 0.7 ppm manganese by AA. Used oil samples were not analyzed at SwRI. At Ethyl's direction, electronic tachographs were installed in the vehicles to monitor highway durability operations.

III. SERVICE ACCUMULATION AND EMISSION TESTS

As requested, service accumulation was conducted on streets and highways such that approximately 68 percent of the mileage was highway driving and 32 percent was AMA city-suburban driving. Using this schedule permitted accumulation of a few more miles per shift than a 50-50 split, shortening the total project time by a few days. Up to 1,000 odometer miles, the vehicles were operated on clear fuel (1194), and thereafter they were operated on treated fuel (1198) for service accumulation. As will be shown later in the report, two emission tests were conducted on clear fuel at the 1,000-mile point, followed by one test using treated fuel. From that point on, all emission tests for this project were conducted using treated fuel.

A description of the service accumulation route is given in Appendix C, along with a summary of operations by day. Note that engine oil and filters were changed when the trucks were received, after the 1,000-mile "clear fuel" emission tests, and then at 9,000, 15,700, and 20,000 miles. The original schedule (out to 25,000 miles) was designed to produce equal durations of oil service after the switch to treated fuel, 8,000 miles on each fill. Note also that in Appendix C is an example record for one shift as recorded by an electronic tachograph. It clearly shows highway miles, the AMA portions, and breaks taken by the driver. All such records are being submitted with this report in a separate data book. Daily reports on status of the test vehicles were submitted to Mr. Hollrah during the project, so are not repeated here. A condensation of these reports, however, is given as a single table in Appendix C. Records of maintenance performed, on-highway fuel consumption and fuel economy, and oil consumption are given in Appendix D.

Emission tests were performed on the vehicles at approximately 1,000, 5,000, 10,000, 15,000, and 20,000 miles, as directed. Originally we had planned to continue out to 25,000 miles, but stopped the project at 20,000 according to Ethyl's request. A summary of FTP emissions data is given in Table 1, and computer printouts for all the tests are given in Appendix E. Particulate data are given only in Table 1 because they were hand-computed after the gaseous printouts were complete. Data for the first test at 1,000 miles on vehicle CP2 appear to show a defective O_2 sensor. All other tests on this vehicle, after sensor replacement, show fairly consistent results indicating a leaner mixture or better oxidizing catalyst efficiency. The only other anomalous data were for the first test at 20,000 miles on vehicle CP3, which on inspection for details showed unexplained higher CO and HC in Bags 3 and 4 than all the other tests. Hydrocarbon and CO values returned to nominal for the repeat test conducted the next day, however.

TABLE 1. SUMMARY OF GASEOUS AND PARTICULATE EMISSIONS

Vehicle	Item	Data by Test Point[a]							
		1,000 Miles			5k Mi	10k Mi	15k Mi	20,000 Miles	
	Test Date	**2/20/91**	**2/22/91**	**2/23/91**	**3/3/91**	**3/11/91**	**3/19/91**	**3/27/91**	**3/28/91**
	Fuel In Use	**1194**	**1194**	**1198**	**1198**	**1198**	**1198**	**1198**	**1198**
CP1	Odometer reading	1,173	1,206	1,247	5,272	10,170	15,174	20,174	
	g/mi part., position 3	0.0023	0.0018	0.0013	0.0016	0.0017	0.00067	0.0010	
	g/mi part., position 5	0.0027	0.0024	0.0017	0.0021	0.0011	0.0010	0.0022	
	HC, g/mi	0.41	0.37	0.28	0.40	0.37	0.43	0.36	
	CO, g/mi	4.67	4.45	3.17	4.39	4.73	3.93	4.71	
	NO_x, g/mi	0.17	0.17	0.16	0.18	0.20	0.19	0.20	
	Fuel Economy, mpg	18.02	18.44	18.82	17.98	18.18	18.58	18.91	
CP2	Odometer reading	1,105	1,137[b]	1,176	4,966	10,105	15,109	20,109	
	g/mi part., position 3	0.0015	0.0015	0.0017	0.00056	0.00071	0.0011	0.00059	
	g/mi part., position 5	0.0021	0.0016	0.002	0.0010	0.00063	0.0018	0.0022	
	HC, g/mi	0.81	0.47	0.42	0.49	0.42	0.36	0.38	
	CO, g/mi	5.90	4.01	3.21	4.61	3.75	3.58	3.63	
	NO_x, g/mi	0.13	0.16	0.14	0.12	0.15	0.11	0.14	
	Fuel Economy, mpg	18.18	18.21	18.13	18.34	18.67	18.52	18.69	
CP3	Odometer reading	1,305	1,335	1,374	5,406	10,304	15,309	20,308	20,337
	g/mi part., position 3	0.0019	0.0017	0.0022	0.00082	0.00079	0.00081	0.00031	0.0014
	g/mi part., position 5	0.0015	0.0023	0.0027	0.00084	0.00021	0.0013	0.00078	0.0022
	HC, g/mi	0.35	0.31	0.25	0.37	0.42	0.38	0.56	0.41
	CO, g/mi	2.86	2.70	2.38	3.32	5.00	4.02	6.52	4.44
	NO_x, g/mi	0.20	0.19	0.18	0.17	0.15	0.18	0.19	0.21
	Fuel Economy, mpg	17.72	17.89	17.80	18.07	17.98	18.24	18.03	18.43

[a] All data tabulated are for 4-bag FTP.
[b] Changed O_2 sensor prior to this test.

Particulate emissions were computed based on the sum of mass collected by sets of two filters in series, a "primary" and a "backup." All particulate emission values are very low, as expected with the vortex/filter systems in place on the vehicles. Part of the variability in these data results from the low sample filter loadings, on the order of 0.01 to 0.05 mg as compared to a desirable loading of 0.5 to 1.8 mg or more. Further analyses of these data are left to Ethyl Corporation unless we are otherwise advised.

Data on manganese emissions in micrograms per mile, based on analysis of particulate filters by both SwRI and Ethyl Corporation, are given in Table 2. Most of these results reflect filter loadings less than the detection limit of the respective procedure(s) used, indicating generally good retention by the onboard vortex/filter systems.

SwRI manganese data by ICP out to 5,000 miles are based on nitric acid digestion and dilution to 25 mL solutions; and those from 10,000 miles on are based on more concentrated 10 mL solutions, hence their lower detection limits. We have no explanation for the comparatively high manganese data observed for vehicles CP2 and CP3 at 5,000 miles. The values were confirmed by a second analysis of the dilute solutions, but must be regarded as anomalous in view of all the other results. Filters taken during the same tests and analyzed by Ethyl showed no corresponding elevated manganese concentrations. For all the manganese analyses, the basis of comparison is the amount of manganese the vehicles were consuming in their fuel during these tests. Based on fuel economy of about 18 mpg and measured manganese concentration in the fuel near the target of 0.03125 g/gallon, manganese consumed by the vehicles was about 1,700 micrograms per mile.

Regarding other tests which indicated measurable amounts of manganese on filters, there was reasonable correlation between values or ranges obtained by SwRI and Ethyl. Such instances include vehicle CP1 at 10k miles and vehicle CP3 at all distances above 5k miles.

IV. POST-TEST ACTIVITIES

Upon completion of the mileage accumulation and emission testing, vehicle exhaust systems were removed and disassembled into manageable sections with great care. This process had been agreed upon earlier, and it was overseen by Mr. Hollrah. The exhaust systems, including pipes, mufflers/converters, vortex separators, and Hepa filters, were packed and shipped to Ethyl in Baton Rouge.

Shortly thereafter, oil pans were removed and packaged, then replaced with new items. Parts removed were sent to Ethyl per instructions. During April, we were asked to disassemble the engine of one vehicle (CP3) to determine the extent of deposits within the engine and manifolds. This work was accomplished with Mr. Hollrah's supervision, resulting in a more complete manganese balance. The engine has now been reassembled, with new parts as necessary (manifold, spark plugs, etc.). We are currently awaiting directions on disposition of the vehicles themselves.

TABLE 2. ANALYSES FOR MANGANESE IN PARTICULATE MATTER

Vehicle	Item		Mn in µg/mile by Test Point[a]							
			1,000 Miles			5k Mi.	10k Mi.	15k Mi.	20,000 Miles	
	Test Date		2/20/91	2/22/91	2/23/91	3/3/91	3/11/91	3/19/91	3/27/91	3/28/91
	Fuel in Use		1194	1194	1198	1198	1198	1198	1198	1198
	Position	Method								
CP1	3 (SwRI)	x-ray	~5.7[b]	----	~5.7[b]	----	----	----	----	
		ICP	<7.9[b]	----	<8.0[b]	<8.2[b]	2.1-3.7[c]	<3.2[b]	<3.1[b]	
	5 (Ethyl)		<3.6[b]	<3.6[b]	<3.5[b]	<3.5[b]	2.0-3.7[c]	<3.5[b]	<3.7[b]	
CP2	3 (SwRI)	x-ray	~0[b]	----	~14[b]	----	----	----	----	
		ICP	<7.9[b]	----	<7.9[b]	162.	<3.2[b]	<3.0[b]	<3.1[b]	
	5 (Ethyl)		<3.7[b]	<3.6[b]	<3.7[b]	<3.6[b]	<3.4[b]	<3.6[b]	<3.6[b]	
CP3	3 (SwRI)	x-ray	~8.5[b]	----	~0[b]	----	----	----	----	----
		ICP	<7.9[b]	----	<7.7[b]	56.	2.5-4.0[c]	<3.1[b]	9.1-11[c]	2.5-4.0[c]
	5 (Ethyl)		<3.7[b]	<3.6[b]	<3.7[b]	<3.7[b]	<3.5[b]	5.2	10-12[c]	3.4-5.2[c]

[a] For 4-bag FTP.
[b] Less than detection limit of instrument or method.
[c] One of two filters less than detection limit.

NOTE: Mn consumed in fuel ~ 1700 µg/mile

V. ACKNOWLEDGEMENTS

Achieving the schedule requested by Ethyl for this project required cooperation by a number of individuals and teams throughout SwRI. The distance accumulation phase was managed by Larry Eckhardt, and driver supervision was performed by Ann Mosley. Filter analysis by ICP was handled by Becky Riddle, and filter mass measurements were performed by Tracy Hill. Data reduction was done by Kathy Jack and Debbie Toles, and emission tests were conducted by Dennis Lovell and Larry Servin. Supervision of the entire experimental phase was performed by Jim Chessher, who is entitled to special credit for his extra efforts to make project go well.

This project also enjoyed the unaccustomed benefits of constant care and attention by an extremely thorough and cooperative representative of the client, who spent many hours at SwRI as well as at other locations making sure the project stayed on track. For performing his job with courtesy and understanding, our particular thanks to Don Hollrah.

VI. CLOSURE

It has been our pleasure performing this project for Ethyl Corporation, and we hope its results will prove to be satisfactory. We look forward to offering our services again as the need arises.

Submitted by:

Charles T. Hare

Charles T. Hare
Director
Department of Emissions Research

CTH/sat

APPENDIX A

ETHYL REQUEST FOR PROPOSAL (12/17/90) AND REVISIONS (1/10/91)

Ethyl

Ethyl Petroleum Additives Division
20 South 4th Street
St. Louis, MO 63102-1886
(314) 421-3930

December 17, 1990

Mr. Charles T. Hare
Director
Department of Emissions Research
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78228-0510

Dear Mr. Hare:

Ethyl Corporation requests Southwest Research Institute (SWRI) to develop a proposal for a manganese emissions project as described below.

Project Objective

The objective of this project is to determine the disposition of manganese particles from vehicles using fuel containing our manganese additive, HiTEC 3000. At the end of the project, Ethyl will analyze for total manganese; that which is emitted from the tailpipe and that which remains in the internal systems of the vehicle, including the motor oil. A trapping apparatus, which will separate larger particles from small ones, will be constructed and attached to the exhaust of the vehicle.

Project Scope

SWRI will accumulate 25,000 miles on 3 vehicles using fuel containing HiTEC 3000 at a concentration of 0.03125 gm Mn/U.S. gallon. The mileage will be accumulated using an approved AMA driving cycle with 50 percent urban and 50 percent highway driving. Mileage will be accumulated 7 days per week using two 10-hour shifts.

Each vehicle will be equipped with a trapping system, to be constructed by an Ethyl contractor, that will accumulate the large and small manganese particulate material emitted from the tailpipe. This equipment will most likely be quite cumbersome so it is Ethyl's intent to use small pickup trucks for mileage accumulation and to place the trapping system in the bed of the pickup.

Every 5,000 miles, SWRI will conduct FTP emission and particulate testing on each vehicle using the particulate tunnel. The particulate testing evaluation is done to make certain that the particulate trapping system on the vehicle is still working properly.

At the end of the mileage accumulation, SWRI will remove the trapping system, the exhaust system, the oil and oil filter from each vehicle and send to Ethyl in Baton Rouge for manganese determination.

Vehicles

The vehicles used in the mileage accumulation will be small General Motors pickups equipped with a 4.3L engine and automatic transmission. These vehicles will be purchased by Ethyl.

Fuel

The fuel used for mileage accumulation will be Howell EEE containing HiTEC 3000 at a concentration of 0.03125 gm Mn/U.S. gallon. Ethyl will provide the HiTEC 3000 additive; SWRI will provide the Howell EEE gasoline and perform the blending. SWRI should conduct an Mn analysis of the final blend to make certain that required amount of HiTEC 3000 is in the gasoline.

Trapping System

Each vehicle will be equipped with a particulate trapping system consisting of an anchored vortex/cyclone separator (to trap larger particulates) and a Hepa filter to trap smaller particulates. Ethyl will provide the required Hepa filters.

Motor Oil

Use motor oil grade as suggested by vehicle manufacturer. Motor oil and oil filter to be changed every 5,000 miles. The used oil and oil filter will be shipped to Ethyl in Baton Rouge.

Driving Cycle

We suggest an AMA driving cycle that includes approximately 50 percent urban driving and 50 percent highway driving; a cycle that will accumulate around 400 miles per shift. Please include some WOT accelerations in the driving cycle.

Mileage Accumulation Procedure

1. Upon receipt of vehicles, conduct FTP emission testing.

2. Install trapping system on each vehicle and conduct particulate testing using particulate tunnel. This is a check to see if trapping system is working properly.

3. Accumulate 1,000 miles and perform testing as in (2).

4. At 5,000 miles and every 5,000 miles thereafter, perform testing as in (1) and (2). Change motor oil and oil filter. Ship used oil and oil filter to Ethyl - PDC in Baton Rouge.

5. At 12,500 miles replace Hepa filter and cyclone container.

6. At end of mileage accumulation, remove trapping system, vehicle exhaust system, oil and oil filter, and ship to Ethyl in Baton Rouge.

Weekly

1. Record max pressure (dual needle gauge) at cyclone inlet and filter inlet.

Please prepare a proposal with associated costs and estimated timing to conduct the project.

Sincerely,

D. P. Hollrah

D. P. Hollrah

DPH:pw

cc: A.D. Brownlow

Ethyl

Ethyl Petroleum Additives Division
20 South 4th Street
St. Louis, MO 63102-1886
(314) 421-3930

January 10, 1991

Fax #512/522-3950

Mr. Charles T. Hare, Director
Department of Emissions Research
Automotive Products and Emissions Division
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78228-0510

Dear Mr. Hare:

After our discussion yesterday on the manganese balance project, the following items represent either changes or additions to your SwRI Proposal No. 08-11016.

1. Ethyl will install the vortex separator and filter holder apparatus, including necessary exhaust tubing, in the three pickups.

2. Mileage accumulation for the first 1,000 miles will be conducted with Howell EEE gasoline without HiTEC 3000.

3. Oil and oil filter will be changed after 1,000 miles and every additional 8,000 miles.

4. Mileage will be accumulated using the 68/32 highway/AMA service accumulation procedure.

5. We do want to use electronic tachograph monitoring.

6. Particulate testing can be done using either the 18-inch tunnel or the 10-inch tunnel depending on which one is active at the time of testing.

I believe this represents all changes or additions. As discussed yesterday, Gary Ter Haar has approved this proposal already and I have made arrangements to get the first check mailed to SwRI. Please review these changes/additions and if the cost changes, then an addendum can be added to the proposal.

Additionally, if you can provide the size of the tank that will be used to house the fuel, we can provide a blend of HiTEC 3000 that will treat the exact amount of fuel.

Sincerely,

Don P. Hollrah

Don P. Hollrah

APPENDIX B

ANALYSIS OF CLEAR FUEL, SwRI CODE 1194

SOUTHWEST RESEARCH INSTITUTE

6220 CULEBRA ROAD • POST OFFICE DRAWER 28510 • SAN ANTONIO, TEXAS, USA 78228-0510 • (512) 684-5111 • TELEX 244846

TABLE. GASOLINE EMISSIONS FUEL SPECIFICATIONS QUALITY ASSURANCE

SUPPLIER HOWELL HYDROCARBONS

LOT NO. 90S-17 SwRI CODE EM-1194-F X Certification
____ Service Accumulation

Item	CFR Specification[a]		Supplier Analysis	SwRI Analyses
	ASTM	Unleaded		
Octane, research, min.	D2699	93	96.0	96.1
Sensitivity, min.		7.5	8.0	8.8
Pb (organic), gm/U.S. gal.	D3237	0.05[b]	0.0	<0.001
Mn, gm/U.S. gal	D3831	--	--	0.001
Distillation Range:				
IBP°F	D86	75-95	90	91
10% Point, °F	D86	120-135	129	129
50% Point, °F	D86	200-230	227	229
90% Point, °F	D86	300-325	313	317
EP, °F (max.	D86	415	391	383
Sulfur, wt. % (max.)	D1266	0.10	0.002	0.008
Phosphorus, gm/U.S.gal. (max.)	D3231	0.005	0.0	0.0001
RVP, psi	D323	8.0-9.2	9.1	8.8
Hydrocarbon Composition:				
Aromatics, % (max.)	D1319	35	32.7	29.1
Olefins, % (max.)	D1319	10	2.5	2.0
Saturates	D1319	c	64.8	68.9

[a]Gasoline fuel specification as in CFR 86.113-90(a)(1) for light-duty gasoline vehicles and CFR 86.1313-90(a)(1) for heavy-duty gasoline engines.
[b]Maximum
[c]Remainder

Supplier Analyses
Date: 10/27/90

SwRI Analyses
by: Karen Kohl
Date: 2/7/91

APPENDIX C

SERVICE ACCUMULATION ROUTE AND CONDENSED LOG

3 TRUCK EMISSIONS TEST

	Miles	MPH	Time			
1. SwRI to Loop 410	2.2	10-40 mp	5.00			
2. Loop 410 to I35 South	10.4	55 mph	11.35			
3. I 35 South to 142	2.6	55 mph	2.84			
4. 142 South to 104 South	37.4	65 mph	34.52			
5. 104 North to 142 North (W.O.T.)	37.4	65 mph	34.52			
6. 142 North to Loop 410	2.6	55 mph	2.84			
7. Loop 410 to Ray Ellison Drive	4.4	55 mph	4.80			
8. AMA times 2	80.0		120.00		1st half route	
9. Old Pearsall Rd. to Culebra (W.O.T.)	9.4	55 mph	10.25	Miles	Time	
10. Culebra to SwRI	2.2	10-40 mp	5.00	188.6	231.12	3.85
11. SwRI to Loop 410	2.2	10-40 mp	5.00			
12. Loop 410 to Ray Ellison Drive exit	6.0	55 mph	6.55			
13. AMA times 1	40.0		60.00			
14. Old Pearsall Rd. to I 35 South (W.O.T.)	1.4	55 mph	1.53			
15. I 35 South to 142	2.6	55 mph	2.84			
16. 142 South to 104 South	37.4	65 mph	34.52			
17. 104 North to 1604 North (W.O.T.)	37.4	65 mph	34.52			
18. 1604 South to 104 South	37.4	65 mph	34.52			
19. 104 North to 142 North (W.O.T.)	37.4	65 mph	34.52			
21. 142 North to Loop 410	2.6	55 mph	2.84		2nd half route	
22. Loop 410 to Culebra	10.4	55 mph	11.35	Miles	Time	
23. Culebra to SwRI	2.2	10-40 mp	5.00	217.0	233.18	3.89
	405.6		464.30			
			7.74			
Plus two 15 min. breaks and 1 30 min. lunch			1.00			
		Total	8.74			

% City Driving **32% (128.8 miles)**

% Highway Driving **68% (276.8 miles)**

Lap	AMA km/hr	mi/hr
1	64 kph	40 mph
2	48 kph	30 mph
3	64 kph	40 mph
4	64 kph	40 mph
5	56 kph	35 mph
6	48 kph	30 mph
7	56 kph	35 mph
8	72 kph	45 mph
9	56 kph	35 mph
10	89 kph	55 mph
11	89 kph	55 mph

W.O.T. denotes wide open throttle.

3 TRUCK EMISSIONS TEST

UNIT NO: ____________________ DATE: ____________________

DRIVER: ____________________

STOP MILES: ____________________ FUEL #1: ____________________

START MILES: FUEL #2:

SHIFT MILES: [ ] TOTAL FUEL: [ ]

	Verify	Pressure Reading
1. SwRI to Loop 410		
2. Loop 410 to I35 South		
3. I 35 South to 142		
4. 142 South to 104 South		
5. 104 North to 142 North (* W.O.T.)		
6. 142 North to Loop 410		
7. Loop 410 to Ray Ellison Drive		
8. AMA times 2		
9. Old Pearsall Rd. to Culebra (* W.O.T.)		
10. Culebra to SwRI		

AMA Number 1

Lap	km/hr	mi/hr	verify
1	64 kph	40 mph	
2	48 kph	30 mph	
3	64 kph	40 mph	
4	64 kph	40 mph	
5	56 kph	35 mph	
6	48 kph	30 mph	
7	56 kph	35 mph	
8	72 kph	45 mph	
9	56 kph	35 mph	
10	89 kph	55 mph	
11	89 kph	55 mph	

Take 30 minute lunch break and refuel vehicle.

11. SwRI to Loop 410	
12. Loop 410 to Ray Ellison Drive exit	
13. AMA times 1	
14. Old Pearsall Rd. to I 35 South (* W.O.T.)	
15. I 35 South to 142	
16. 142 South to 104 South	
17. 104 North to 1604 North (* W.O.T.)	
18. 1604 South to 104 South	
19. 104 North to 142 North (* W.O.T.)	
21. 142 North to Loop 410	
22. Loop 410 to Culebra	
23. Culebra to SwRI	

AMA Number 2

Lap	km/hr	mi/hr	verify
1	64 kph	40 mph	
2	48 kph	30 mph	
3	64 kph	40 mph	
4	64 kph	40 mph	
5	56 kph	35 mph	
6	48 kph	30 mph	
7	56 kph	35 mph	
8	72 kph	45 mph	
9	56 kph	35 mph	
10	89 kph	55 mph	
11	89 kph	55 mph	

AMA Number 3

Lap	km/hr	mi/hr	verify
1	64 kph	40 mph	
2	48 kph	30 mph	
3	64 kph	40 mph	
4	64 kph	40 mph	
5	56 kph	35 mph	
6	48 kph	30 mph	
7	56 kph	35 mph	
8	72 kph	45 mph	
9	56 kph	35 mph	
10	89 kph	55 mph	
11	89 kph	55 mph	

* W.O.T. denotes wide open throttle. Decelerate at the highway entrance ramp to 20 mph, then accelerate to lap speed. W.O.T. ONLY AS ROAD CONDITIONS, TRAFFIC AND OTHER OTHER FACTORS ALLOW. Wheels are not to be spun and saftey is not to be compromised.

<u>SAFETY FIRST!!!!!</u>

Silent Witness Enterprises

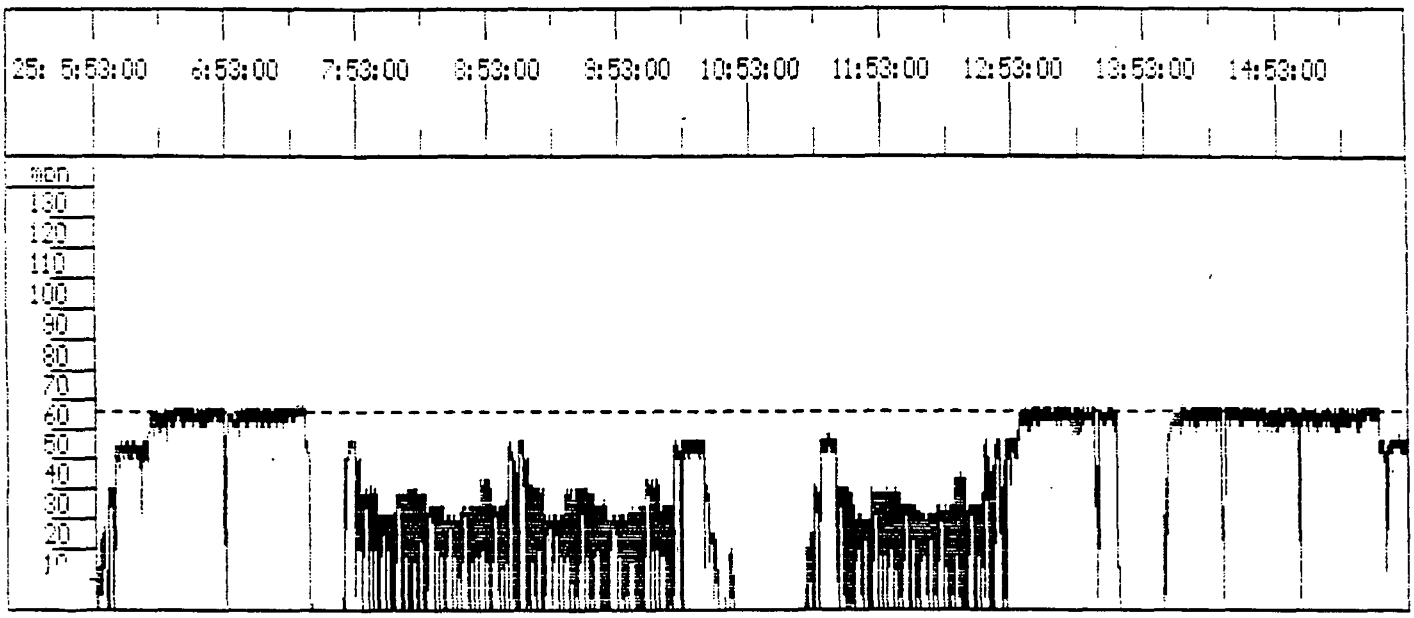
Southwest Research Test Fleet

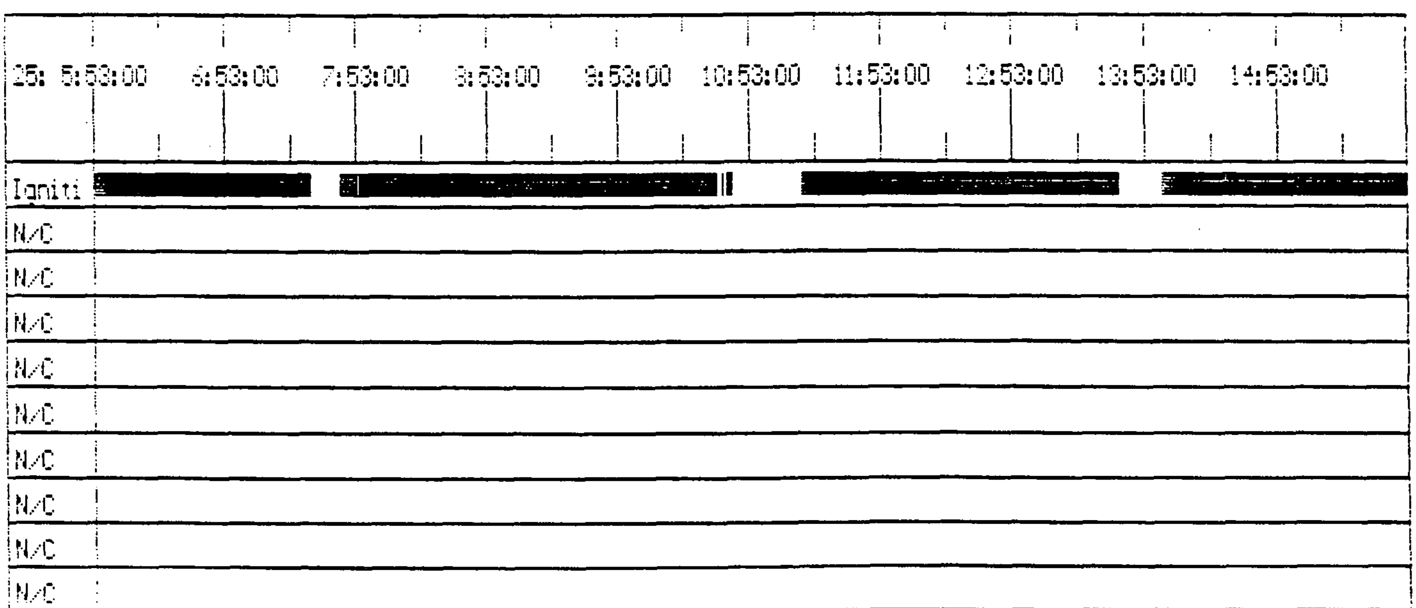
Date Printed: Mar 26 1991 at 17:02:58

Data File: CP1MR25.KBB
GPIP File: CP1.CAR
Vehicle : CP1

StartTime: Mar 24 1991 at 16:16:54
EndTime: Mar 25 1991 at 16:16:54

10 Hour Minute By Minute Graph - 1440 minutes





CONDENSED SERVICE ACCUMULATION LOG

Date	Odometer Reading at End of Day by Vehicle		
	CP1	CP2	CP3
2/14/91	669	586	786
2/15/91	1165	1097	1296
	-----Hold for emission tests------		
2/24/91	1846	1697	2027
2/25/91	2647	2502	2827
2/27/91	3451	3309	3628
2/28/91	4247	3590	4244
3/1/91	5042	4384	5039
3/2/91	5265	4959	5398
	-----Hold for emission tests------		
3/3/91	5691	5384	5824
3/4/91	6485	6158	6618
3/5/91	7233	6892	7353
3/6/91	8028	7725	8147
3/7/91	8776	8568	8891
3/8/91	9459	9381	9614
3/9/91	10163	10097	10296
3/11/91	10592	10455	10653
	-----Hold for emission tests------		
3/12/91	11316	11178	11376
3/13/91	12066	11929	12127
3/14/91	12815	12705	12851
3/15/91	13541	13428	13575
3/16/91	14116	14003	14151
3/17/91	14878	14783	14904
3/18/91	15162	15097	15296
	-----Hold for emission tests------		
3/19/91	15592	15526	15727
3/20/91	16258	16196	16449
3/21/91	17052	16937	17245
3/22/91	17846	17735	18038
3/23/91	18603	18532	18796
3/24/91	19403	19335	19591
3/25/91	20162	20097	20296

APPENDIX D

MAINTENANCE RECORDS
FUEL CONSUMPTION AND FUEL ECONOMY
OIL CONSUMPTION

Maintenance Record
CP-1

Date	Odometer Miles	Action
13-Feb-91	126	Removed 8 oz. sample. The oil was drained and a new filter was installed. The engine was refilled with Quaker State 10-W-30 oil. The engine was run for 10 minutes, then the engine was drained and refilled with new oil and a new filter was installed. The engine was run for five minutes and an eight oz. sample was taken.
15-Feb-91	1,165	Drained engine oil into clean pan, caught all the oil from the pan and filter. Refilled the engine with new oil and installed a new filter.
8-Mar-91	9,114	Performed preventive maintenance and changed the oil.
19-Mar-91	15,771	Performed preventive maintenance and changed the oil. Added 1/2 quart of oil.
25-Mar-91	20,162	At the end of the test, the used oil and used filter were saved for shipment. The oil pan was also removed for shipment.

Maintenance Record
CP-2

Date	*Odometer Miles*	*Action*
13-Feb-91	97	Removed 8 oz. sample. The oil was drained and a new filter was installed. The engine was refilled with Quaker State 10-W-30 oil. The engine was run for 10 minutes, then the engine was drained and refilled with new oil and a new filter was installed. The engine was run for five minutes and an eight oz. sample was taken.
15-Feb-91	1,097	Drained engine oil into clean pan, caught all the oil from the pan and filter. Refilled the engine with new oil and installed a new filter.
28-Feb-91	3,741	As a result of accident, all 4 tire pressures were checked and recorded as follows: left front 32, right front 32, left rear 36, and right rear 36. The truck was taken to a dealer to check the brake system for proper operation. Nothing was found wrong with the system.
8-Mar-91	8,961	Performed preventive maintenance and changed the oil.
19-Mar-91	15,707	Performed preventive maintenance and changed the oil. Added 3/4 quart of oil.
25-Mar-91	20,097	At the end of the test, the used oil and used filter were saved for shipment. The oil pan was also removed for shipment.

Maintenance Record
CP-3

Date	*Odometer Miles*	*Action*
13-Feb-91	296	Removed 8 oz. sample. The oil was drained and a new filter was installed. The engine was refilled with Quaker State 10-W-30 oil. The engine was run for 10 minutes, then the engine was drained and refilled with new oil and a new filter was installed. The engine was run for five minutes and an eight oz. sample was taken.
15-Feb-91	1,229	Drained engine oil into clean pan, caught all the oil from the pan and filter. Refilled the engine with new oil and installed a new filter.
8-Mar-91	9,285	Performed preventive maintenance and changed the oil.
19-Mar-91	15,906	Performed preventive maintenance and changed the oil. Added 1/4 quart of oil.
25-Mar-91	20,296	At the end of the test, the used oil and used filter were saved for shipment. The oil pan was also removed for shipment.

Fuel Consumption and Economy
CP-1

Date	Last Odometer	Current Odometer	Shift Miles	Fuel Used	MPG
14-Feb-91	162	669	507	29.8	17.0
15-Feb-91	669	1,165	496	26.4	18.8
25-Feb-91	1,165	1,846	681	36.2	18.8
26-Feb-91	1,846	2,647	801	35.5	22.6
27-Feb-91	2,647	3,451	804	35.8	22.5
28-Feb-91	3,451	4,247	796	36.3	21.9
1-Mar-91	4,247	5,042	795	35.6	22.3
2-Mar-91	5,042	5,265	223	8.0	27.9
3-Mar-91	5,265	5,691	426	17.8	23.9
4-Mar-91	5,691	6,483	792	34.9	22.7
5-Mar-91	6,483	7,233	750	32.9	22.8
6-Mar-91	7,233	8,028	795	34.2	23.2
7-Mar-91	8,028	8,776	748	33.8	22.1
8-Mar-91	8,776	9,459	683	31.1	22.0
9-Mar-91	9,459	10,163	704	25.0	28.2
11-Mar-91	10,163	10,592	429	19.2	22.3
12-Mar-91	10,592	11,316	724	32.6	22.2
13-Mar-91	11,316	12,066	750	33.2	22.6
14-Mar-91	12,066	12,815	749	33.1	22.6
15-Mar-91	12,815	13,541	726	33.7	21.5
16-Mar-91	13,541	14,116	575	26.0	22.1
17-Mar-91	14,116	14,878	762	33.5	22.7
18-Mar-91	14,878	15,162	284	8.0	35.5
19-Mar-91	15,162	15,592	430	26.3	16.3
20-Mar-91	15,592	16,258	666	31.0	21.5
21-Mar-91	16,258	17,052	794	36.2	21.9
22-Mar-91	17,052	17,846	794	34.9	22.8
23-Mar-91	17,846	18,603	757	31.8	23.8
24-Mar-91	18,603	19,403	800	34.2	23.4
25-Mar-91	19,403	20,162	759	27.2	27.9

Total Test Miles: 20,000 **Total Fuel: 894.2**

Average Fuel Economy: $\boxed{22.4}$

Fuel Consumption and Economy
CP-2

Date	Last Odometer	Current Odometer	Shift Miles	Fuel Used	MPG
14-Feb-91	97	586	489	21.5	22.7
15-Feb-91	586	1,097	511	22.8	22.4
25-Feb-91	1,097	1,697	600	24.5	24.5
26-Feb-91	1,697	2,502	805	35.3	22.8
27-Feb-91	2,502	3,309	807	36.2	22.3
28-Feb-91	3,309	3,590	281	13.0	21.6
1-Mar-91	3,590	4,384	794	35.6	22.3
2-Mar-91	4,384	4,959	575	17.7	32.5
3-Mar-91	4,959	5,384	425	18.3	23.2
4-Mar-91	5,384	6,158	774	34.1	22.7
5-Mar-91	6,158	6,892	734	32.1	22.9
6-Mar-91	6,892	7,725	833	37.0	22.5
7-Mar-91	7,725	8,568	843	36.4	23.2
8-Mar-91	8,568	9,381	813	35.7	22.8
9-Mar-91	9,381	10,097	716	25.3	28.3
11-Mar-91	10,097	10,455	358	17.0	21.1
12-Mar-91	10,455	11,178	723	28.7	25.2
13-Mar-91	11,178	11,929	751	32.5	23.1
14-Mar-91	11,929	12,705	776	34.5	22.5
15-Mar-91	12,705	13,428	723	33.2	21.8
16-Mar-91	13,428	14,003	575	26.5	21.7
17-Mar-91	14,003	14,783	780	35.1	22.2
18-Mar-91	14,783	15,097	314	8.0	39.3
19-Mar-91	15,097	15,526	429	19.2	22.3
20-Mar-91	15,526	16,196	670	31.5	21.3
21-Mar-91	16,196	16,937	741	35.1	21.1
22-Mar-91	16,937	17,735	798	35.7	22.4
23-Mar-91	17,735	18,532	797	35.1	22.7
24-Mar-91	18,532	19,335	803	35.6	22.6
25-Mar-91	19,335	20,097	762	27.6	27.6

Total Test Miles: 20,000 **Total Fuel: 860.8**

Average Fuel Economy: 23.2

Fuel Consumption and Economy
CP-3

Date	Last Odometer	Current Odometer	Shift Miles	Fuel Used	MPG
14-Feb-91	296	786	490	22.5	21.8
15-Feb-91	786	1,296	510	14.0	36.4
25-Feb-91	1,296	2,027	731	32.0	22.8
26-Feb-91	2,027	2,827	800	37.6	21.3
27-Feb-91	2,827	3,628	801	37.9	21.1
28-Feb-91	3,628	4,244	616	27.8	22.2
1-Mar-91	4,244	5,039	795	39.5	20.1
2-Mar-91	5,039	5,398	359	9.0	39.9
3-Mar-91	5,398	5,824	426	19.5	21.8
4-Mar-91	5,824	6,618	794	37.3	21.3
5-Mar-91	6,618	7,353	735	34.5	21.3
6-Mar-91	7,353	8,147	794	36.4	21.8
7-Mar-91	8,147	8,891	744	35.0	21.3
8-Mar-91	8,891	9,614	723	36.2	20.0
9-Mar-91	9,614	10,296	682	18.1	37.7
11-Mar-91	10,296	10,653	357	17.4	20.5
12-Mar-91	10,653	11,376	723	34.3	21.1
13-Mar-91	11,376	12,127	751	35.0	21.5
14-Mar-91	12,127	12,851	724	34.5	21.0
15-Mar-91	12,851	13,575	724	34.3	21.1
16-Mar-91	13,575	14,151	576	27.0	21.3
17-Mar-91	14,151	14,904	753	35.0	21.5
18-Mar-91	14,904	15,296	392	8.0	49.0
19-Mar-91	15,296	15,727	431	20.5	21.0
20-Mar-91	15,727	16,449	722	34.0	21.2
21-Mar-91	16,449	17,245	796	38.5	20.7
22-Mar-91	17,245	18,038	793	35.2	22.5
23-Mar-91	18,038	18,796	758	32.8	23.1
24-Mar-91	18,796	19,591	795	35.5	22.4
25-Mar-91	19,591	20,296	705	27.9	25.3

Total Test Miles: 20,000 **Total Fuel: 887.2**

Average Fuel Economy: 22.5

Oil Consumption Data

CP1

Accumulative Oil Con: 31,290.0 mile/qt.

Oil Drain No.	Previous Drain Odometer	Current Drain Odometer	Actual Miles	Quarts Used	Mile/ Quart
1	126.0	1,165.0	1,039.0	0.00	n/a
2	1,165.0	9,114.0	7,949.0	0.00	n/a
3	9,114.0	15,771.0	6,657.0	0.50	13,314.0

CP2

Accumulative Oil Con: 20,813.3 mile/qt.

Oil Drain No.	Previous Drain Odometer	Current Drain Odometer	Actual Miles	Quarts Used	Mile/ Quart
1	97.0	1,097.0	1,000.0	0.00	n/a
2	1,097.0	8,961.0	7,864.0	0.00	n/a
3	8,961.0	15,707.0	6,746.0	0.75	8,994.7

CP3

Accumulative Oil Con: 62,440.0 mile/qt.

Oil Drain No.	Previous Drain Odometer	Current Drain Odometer	Actual Miles	Quarts Used	Mile/ Quart
1	296.0	1,229.0	933.0	0.00	n/a
2	1,229.0	9,285.0	8,056.0	0.00	n/a
3	9,285.0	15,906.0	6,621.0	0.25	26,484.0

APPENDIX E

COMPUTER PRINTOUTS OF GASEOUS EMISSION TEST RESULTS

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - 1000 MI
PROJECT 08-4070-001

TEST NO. 1 RUN	VEHICLE NO.CP1	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/20/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1194-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 1888. KM(1173. MILES)

BAROMETER 749.05 MM HG(29.49 IN HG) DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)
RELATIVE HUMIDITY 23. PCT ABS. HUMIDITY 4.4 GM/KG NOX HUMIDITY CORRECTION FACTOR .83

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	39.4 (103.0)		37.8 (100.0)	40.0 (104.0)		38.9 (102.0)
BLOWER REVOLUTIONS	40245.		68880.	40073.		68750.
TOT FLOW STD. CU. METRES(SCF)	74.0 (2613.)		127.3 (4496.)	73.5 (2596.)		126.6 (4471.)
THC SAMPLE METER/RANGE/PPM	10.7/ 3/ 107.		9.3/ 2/ 9.	51.2/ 2/ 51.		10.9/ 2/ 11.
THC BCKGRD METER/RANGE/PPM	.8/ 3/ 8.		7.8/ 2/ 8.	8.8/ 2/ 9.		8.8/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	62.0/ 1/ 557.		21.4/ 12/ 21.	95.8/ 13/ 237.		33.6/ 12/ 33.
CO BCKGRD METER/RANGE/PPM	.1/ 1/ 1.		1.1/ 12/ 1.	.0/ 13/ 0.		.5/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	75.1/ 1/1.3881		91.0/ 14/ .8915	64.6/ 1/1.1953		90.2/ 14/ .8719
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0437		13.2/ 14/ .0446	2.4/ 1/ .0420		13.0/ 14/ .0438
NOX SAMPLE METER/RANGE/PPM	89.7/ 1/ 22.4		3.1/ 1/ .8	4.4/ 1/ 1.2		2.9/ 1/ .8
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .1		.8/ 1/ .2	1.0/ 1/ .3		.9/ 1/ .2
DILUTION FACTOR	9.23		14.98	10.95		15.29
THC CONCENTRATION PPM	100.		2.	43.		3.
CO CONCENTRATION PPM	537.		20.	230.		32.
CO2 CONCENTRATION PCT	1.3491		.8499	1.1572		.8310
NOX CONCENTRATION PPM	22.3		.6	.9		.5
THC MASS GRAMS	4.25		.15	1.83		.20
CO MASS GRAMS	46.26		2.94	19.66		4.74
CO2 MASS GRAMS	1827.6		1981.5	1557.8		1926.2
NOX MASS GRAMS	2.61		.12	.11		.11
THC GRAMS/MI	1.17		.04	.51		.05
CO GRAMS/MI	12.75		.76	5.43		1.23
CO2 GRAMS/MI	503.6		509.8	430.6		498.9
NOX GRAMS/MI	.72		.03	.03		.03
FUEL ECONOMY IN MPG	16.82	17.09	17.35	20.12	18.79	17.70
RUN TIME SECONDS	505.		867.	504.		867.
MEASURED DISTANCE MI	3.63	7.52	3.89	3.62	7.48	3.86
SCF, DRY	.980	.983	.984	.982	.983	.985
DFC, WET (DRY)		.918(.911)			.925(.918)	
TOT VOL (SCM) / SAM BLR (SCM)		201.3/ .00			200.1/ .00	

COMPOSITE RESULTS

TEST NUMBER		1
BAROMETER	MM HG	749.0
HUMIDITY	G/KG	4.4
TEMPERATURE	DEG C	24.4

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	486.8	(483.5)
FUEL ECONOMY	MPG	17.91	(18.02)
HYDROCARBONS (THC)	G/MI	.40	(.41)
CARBON MONOXIDE	G/MI	4.53	(4.67)
OXIDES OF NITROGEN	G/MI	.17	(.17)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - 1000 MI
PROJECT 08-4070-001

TEST NO. 1 RUN	VEHICLE NO.CP2	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/20/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1194-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 1778. KM(1105. MILES)

BAROMETER 748.54 MM HG(29.47 IN HG)	DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)	
RELATIVE HUMIDITY 17. PCT	ABS. HUMIDITY 3.3 GM/KG	NOX HUMIDITY CORRECTION FACTOR .80

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		39.4 (103.0)	42.2 (108.0)		39.4 (103.0)
BLOWER REVOLUTIONS	40133.		68737.	40060.		68767.
TOT FLOW STD. CU. METRES(SCF)	72.8 (2569.)		126.2 (4458.)	72.9 (2574.)		126.3 (4460.)
THC SAMPLE METER/RANGE/PPM	9.8/ 3/ 98.		52.4/ 2/ 52.	75.1/ 2/ 75.		42.3/ 2/ 42.
THC BCKGRD METER/RANGE/PPM	.9/ 3/ 9.		8.1/ 2/ 8.	8.0/ 2/ 8.		8.4/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	70.2/ 14/ 331.		67.6/ 13/ 162.	58.8/ 14/ 268.		52.7/ 13/ 124.
CO BCKGRD METER/RANGE/PPM	.2/ 14/ 1.		.5/ 13/ 1.	.3/ 14/ 1.		.2/ 13/ 0.
CO2 SAMPLE METER/RANGE/PCT	75.5/ 1/1.3955		90.0/ 14/ .8671	64.5/ 1/1.1935		89.8/ 14/ .8623
CO2 BCKGRD METER/RANGE/PCT	2.3/ 1/ .0402		12.9/ 14/ .0434	2.4/ 1/ .0420		12.7/ 14/ .0426
NOX SAMPLE METER/RANGE/PPM	77.5/ 1/ 19.4		.8/ 1/ .2	2.1/ 1/ .6		.6/ 1/ .2
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .1		.6/ 1/ .2	.5/ 1/ .1		.4/ 1/ .1
DILUTION FACTOR	9.32		15.09	10.92		15.25
THC CONCENTRATION PPM	90.		45.	68.		34.
CO CONCENTRATION PPM	319.		157.	259.		120.
CO2 CONCENTRATION PCT	1.3596		.8266	1.1554		.8225
NOX CONCENTRATION PPM	19.3		.1	.4		.1
THC MASS GRAMS	3.76		3.26	2.85		2.51
CO MASS GRAMS	27.03		23.05	21.99		17.72
CO2 MASS GRAMS	1811.0		1910.4	1541.9		1901.8
NOX MASS GRAMS	2.16		.01	.05		.01
THC GRAMS/MI	1.04		.84	.79		.65
CO GRAMS/MI	7.48		5.95	6.10		4.57
CO2 GRAMS/MI	500.9		493.0	427.7		490.8
NOX GRAMS/MI	.60		.00	.01		.00
FUEL ECONOMY IN MPG	17.19	17.38	17.56	20.16	18.83	17.73
RUN TIME SECONDS	506.		867.	505.		867.
MEASURED DISTANCE MI	3.62	7.49	3.88	3.60	7.48	3.87
SCF, DRY	.982	.985	.986	.983	.985	.987
DFC, WET (DRY)		.919(.914)			.925(.920)	
TOT VOL (SCM) / SAM BLR (SCM)		199.0/ .00			199.2/ .00	

COMPOSITE RESULTS

TEST NUMBER		1
BAROMETER	MM HG	748.5
HUMIDITY	G/KG	3.3
TEMPERATURE	DEG C	24.4

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	476.7	(476.1)
FUEL ECONOMY	MPG	18.12	(18.18)
HYDROCARBONS (THC)	G/MI	.87	(.81)
CARBON MONOXIDE	G/MI	6.31	(5.90)
OXIDES OF NITROGEN	G/MI	.13	(.13)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS - 1000 MI
PROJECT 08-4070-001

TEST NO. 1 RUN	VEHICLE NO.CP3	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/20/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1194-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 2100. KM(1305. MILES)

BAROMETER 748.03 MM HG(29.45 IN HG) — DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
RELATIVE HUMIDITY 18. PCT — ABS. HUMIDITY 3.6 GM/KG — NOX HUMIDITY CORRECTION FACTOR .81

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H20(IN. H20)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H20(IN. H20)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		40.6 (105.0)	42.2 (108.0)		40.6 (105.0)
BLOWER REVOLUTIONS	40127.		68812.	40054.		68758.
TOT FLOW STD. CU. METRES(SCF)	72.7 (2567.)		125.8 (4442.)	72.8 (2571.)		125.7 (4439.)
THC SAMPLE METER/RANGE/PPM	10.0/ 3/ 100.		9.0/ 2/ 9.	43.7/ 2/ 44.		9.4/ 2/ 9.
THC BCKGRD METER/RANGE/PPM	1.0/ 3/ 10.		8.1/ 2/ 8.	7.9/ 2/ 8.		8.0/ 2/ 8.
CO SAMPLE METER/RANGE/PPM	73.2/ 14/ 348.		5.9/ 12/ 6.	73.9/ 13/ 178.		10.6/ 12/ 11.
CO BCKGRD METER/RANGE/PPM	.5/ 14/ 2.		2.6/ 12/ 3.	1.5/ 13/ 3.		2.1/ 12/ 2.
CO2 SAMPLE METER/RANGE/PCT	76.6/ 1/1.4158		92.0/ 14/ .9168	67.2/ 1/1.2429		91.4/ 14/ .9015
CO2 BCKGRD METER/RANGE/PCT	2.3/ 1/ .0402		12.9/ 14/ .0434	2.6/ 1/ .0455		15.0/ 14/ .0519
NOX SAMPLE METER/RANGE/PPM	27.9/ 2/ 28.0		2.0/ 1/ .5	2.2/ 1/ .6		2.0/ 1/ .5
NOX BCKGRD METER/RANGE/PPM	.0/ 2/ .0		.3/ 1/ .1	.5/ 1/ .1		.5/ 1/ .1
DILUTION FACTOR	9.18		14.59	10.60		14.83
THC CONCENTRATION PPM	91.		1.	37.		2.
CO CONCENTRATION PPM	334.		3.	170.		8.
CO2 CONCENTRATION PCT	1.3800		.8763	1.2017		.8531
NOX CONCENTRATION PPM	28.0		.5	.5		.4
THC MASS GRAMS	3.81		.11	1.53		.14
CO MASS GRAMS	28.29		.50	14.38		1.24
CO2 MASS GRAMS	1836.6		2018.5	1602.2		1963.5
NOX MASS GRAMS	3.15		.09	.05		.08
THC GRAMS/MI	1.06		.03	.42		.04
CO GRAMS/MI	7.89		.13	3.98		.32
CO2 GRAMS/MI	511.9		524.2	443.8		508.8
NOX GRAMS/MI	.88		.02	.01		.02
FUEL ECONOMY IN MPG	16.81	16.86	16.91	19.65	18.42	17.41
RUN TIME SECONDS	505.		868.	505.		868.
MEASURED DISTANCE MI	3.59	7.44	3.85	3.61	7.47	3.86
SCF, DRY	.981	.984	.986	.983	.985	.986
DFC, WET (DRY)		.917(.911)			.923(.917)	
TOT VOL (SCM) / SAM BLR (SCM)		198.5/ .00			198.5/ .00	

COMPOSITE RESULTS

TEST NUMBER	1
BAROMETER MM HG	748.0
HUMIDITY G/KG	3.6
TEMPERATURE DEG C	25.0

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	499.5	(495.0)
FUEL ECONOMY	MPG	17.56	(17.72)
HYDROCARBONS (THC)	G/MI	.35	(.35)
CARBON MONOXIDE	G/MI	2.80	(2.86)
OXIDES OF NITROGEN	G/MI	.20	(.20)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS -
PROJECT 08-4070-001

TEST NO. 2 RUN 2	VEHICLE NO.CP1	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/22/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1194-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 1941. KM(1206. MILES)
BAROMETER 745.24 MM HG(29.34 IN HG)	DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)	
RELATIVE HUMIDITY 29. PCT	ABS. HUMIDITY 5.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR .85

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.7 (107.0)		40.6 (105.0)	40.6 (105.0)		40.0 (104.0)
BLOWER REVOLUTIONS	40257.		68968.	40164.		68828.
TOT FLOW STD. CU. METRES(SCF)	73.0 (2579.)		125.6 (4434.)	73.1 (2582.)		125.5 (4433.)
THC SAMPLE METER/RANGE/PPM	10.6/ 3/ 106.		9.2/ 2/ 9.	38.1/ 2/ 38.		11.5/ 2/ 11.
THC BCKGRD METER/RANGE/PPM	.6/ 3/ 6.		6.6/ 2/ 7.	7.9/ 2/ 8.		9.1/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	60.5/ 1/ 539.		23.5/ 12/ 23.	48.4/ 14/ 214.		36.9/ 12/ 37.
CO BCKGRD METER/RANGE/PPM	.2/ 1/ 1.		.9/ 12/ 1.	.0/ 14/ 0.		.4/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	74.7/ 1/1.3807		90.5/ 14/ .8792	63.3/ 1/1.1715		89.8/ 14/ .8623
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0420		13.1/ 14/ .0442	2.5/ 1/ .0437		12.8/ 14/ .0430
NOX SAMPLE METER/RANGE/PPM	81.3/ 1/ 20.4		3.4/ 1/ .9	7.5/ 1/ 2.0		2.7/ 1/ .7
NOX BCKGRD METER/RANGE/PPM	1.3/ 1/ .3		1.1/ 1/ .3	.6/ 1/ .2		.7/ 1/ .2
DILUTION FACTOR	9.28		15.19	11.20		15.46
THC CONCENTRATION PPM	100.		3.	31.		3.
CO CONCENTRATION PPM	519.		22.	207.		35.
CO2 CONCENTRATION PCT	1.3432		.8379	1.1317		.8221
NOX CONCENTRATION PPM	20.1		.6	1.8		.5
THC MASS GRAMS	4.23		.22	1.30		.22
CO MASS GRAMS	44.10		3.21	17.64		5.17
CO2 MASS GRAMS	1796.1		1926.4	1515.2		1889.4
NOX MASS GRAMS	2.37		.13	.21		.11
THC GRAMS/MI	1.17		.06	.36		.06
CO GRAMS/MI	12.20		.83	4.91		1.33
CO2 GRAMS/MI	496.7		495.2	421.5		486.5
NOX GRAMS/MI	.65		.03	.06		.03
FUEL ECONOMY IN MPG	17.07	17.47	17.86	20.60	19.25	18.14
RUN TIME SECONDS	505.		867.	505.		868.
MEASURED DISTANCE MI	3.62	7.51	3.89	3.59	7.48	3.88
SCF, DRY	.978	.981	.982	.980	.982	.983
DFC, WET (DRY)		.919(.910)			.926(.917)	
TOT VOL (SCM) / SAM BLR (SCM)		198.6/ .00			198.7/ .00	

COMPOSITE RESULTS

TEST NUMBER		2
BAROMETER	MM HG	745.2
HUMIDITY	G/KG	5.1
TEMPERATURE	DEG C	22.8

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	475.3	(472.7)
FUEL ECONOMY	MPG	18.35	(18.44)
HYDROCARBONS (THC)	G/MI	.37	(.37)
CARBON MONOXIDE	G/MI	4.30	(4.45)
OXIDES OF NITROGEN	G/MI	.17	(.17)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH
FTP - VEHICLE EMISSIONS RESULTS -
PROJECT 08-4070-001

TEST NO. 2 RUN 2	VEHICLE NO.CP2	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/22/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1194-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 1830. KM(1137. MILES)
BAROMETER 745.24 MM HG(29.34 IN HG)	DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)	
RELATIVE HUMIDITY 33. PCT	ABS. HUMIDITY 5.7 GM/KG	NOX HUMIDITY CORRECTION FACTOR .86

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		42.2 (108.0)	43.3 (110.0)		42.8 (109.0)
BLOWER REVOLUTIONS	40076.		68733.	40039.		68662.
TOT FLOW STD. CU. METRES(SCF)	72.3 (2552.)		124.4 (4393.)	72.2 (2550.)		124.1 (4380.)
THC SAMPLE METER/RANGE/PPM	82.5/ 2/ 82.		19.8/ 2/ 20.	56.5/ 2/ 56.		21.5/ 2/ 21.
THC BCKGRD METER/RANGE/PPM	9.5/ 2/ 9.		8.6/ 2/ 9.	7.9/ 2/ 8.		7.1/ 2/ 7.
CO SAMPLE METER/RANGE/PPM	70.3/ 14/ 331.		51.3/ 12/ 51.	51.8/ 14/ 231.		57.0/ 12/ 57.
CO BCKGRD METER/RANGE/PPM	.2/ 14/ 1.		.3/ 12/ 0.	.0/ 14/ 0.		.0/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	74.9/ 1/1.3844		90.8/ 14/ .8866	65.0/ 1/1.2027		90.4/ 14/ .8768
CO2 BCKGRD METER/RANGE/PCT	2.2/ 1/ .0384		12.3/ 14/ .0411	2.3/ 1/ .0402		12.2/ 14/ .0407
NOX SAMPLE METER/RANGE/PPM	88.1/ 1/ 22.0		1.0/ 1/ .3	3.2/ 1/ .8		.6/ 1/ .2
NOX BCKGRD METER/RANGE/PPM	.6/ 1/ .2		.5/ 1/ .1	.6/ 1/ .2		.1/ 1/ .0
DILUTION FACTOR	9.41		15.00	10.89		15.15
THC CONCENTRATION PPM	74.		12.	49.		15.
CO CONCENTRATION PPM	318.		49.	223.		55.
CO2 CONCENTRATION PCT	1.3500		.8482	1.1661		.8388
NOX CONCENTRATION PPM	21.9		.1	.7		.1
THC MASS GRAMS	3.08		.84	2.05		1.06
CO MASS GRAMS	26.77		7.15	18.79		7.97
CO2 MASS GRAMS	1786.5		1932.2	1541.7		1905.0
NOX MASS GRAMS	2.60		.03	.08		.03
THC GRAMS/MI	.86		.22	.57		.28
CO GRAMS/MI	7.47		1.86	5.24		2.07
CO2 GRAMS/MI	498.3		502.5	430.0		494.2
NOX GRAMS/MI	.73		.01	.02		.01
FUEL ECONOMY IN MPG	17.29	17.41	17.52	20.15	18.86	17.80
RUN TIME SECONDS	505.		867.	505.		867.
MEASURED DISTANCE MI	3.59	7.43	3.85	3.59	7.44	3.85
SCF, DRY	.977	.980	.981	.978	.980	.981
DFC, WET (DRY)		.919(.909)			.924(.915)	
TOT VOL (SCM) / SAM BLR (SCM)		196.7/ .00			196.3/ .00	

COMPOSITE RESULTS

TEST NUMBER		2
BAROMETER	MM HG	745.2
HUMIDITY	G/KG	5.7
TEMPERATURE	DEG C	22.8

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	481.7	(479.2)
FUEL ECONOMY	MPG	18.12	(18.21)
HYDROCARBONS (THC)	G/MI	.45	(.47)
CARBON MONOXIDE	G/MI	3.95	(4.01)
OXIDES OF NITROGEN	G/MI	.16	(.16)

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TEST NO. 2 RUN 2	VEHICLE NO.CP3	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/22/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1194-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 2148. KM(1335. MILES)
BAROMETER 743.20 MM HG(29.26 IN HG)	DRY BULB TEMP. 27.2 DEG C(81.0 DEG F)	
RELATIVE HUMIDITY 30. PCT	ABS. HUMIDITY 7.0 GM/KG	NOX HUMIDITY CORRECTION FACTOR .89

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H20(IN. H20)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H20(IN. H20)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.9 (111.0)		45.0 (113.0)	43.9 (111.0)		42.8 (109.0)
BLOWER REVOLUTIONS	40015.		68691.	40093.		68710.
TOT FLOW STD. CU. METRES(SCF)	71.8 (2536.)		122.9 (4338.)	72.0 (2541.)		123.8 (4370.)
THC SAMPLE METER/RANGE/PPM	88.9/ 2/ 89.		8.9/ 2/ 9.	35.2/ 2/ 35.		6.6/ 2/ 7.
THC BCKGRD METER/RANGE/PPM	6.4/ 2/ 6.		6.7/ 2/ 7.	6.1/ 2/ 6.		6.3/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	70.5/ 14/ 332.		12.1/ 12/ 12.	70.5/ 13/ 169.		2.8/ 12/ 3.
CO BCKGRD METER/RANGE/PPM	.1/ 14/ 0.		.9/ 12/ 1.	.4/ 13/ 1.		.6/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	78.3/ 1/1.4474		92.5/ 14/ .9297	67.3/ 1/1.2447		91.6/ 14/ .9066
CO2 BCKGRD METER/RANGE/PCT	2.8/ 1/ .0490		14.5/ 14/ .0498	2.9/ 1/ .0508		14.8/ 14/ .0510
NOX SAMPLE METER/RANGE/PPM	91.3/ 1/ 22.8		1.5/ 1/ .4	5.0/ 1/ 1.3		2.9/ 1/ .8
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ .1		.5/ 1/ .1	.4/ 1/ .1		.5/ 1/ .1
DILUTION FACTOR	9.00		14.38	10.60		14.77
THC CONCENTRATION PPM	83.		3.	30.		1.
CO CONCENTRATION PPM	319.		11.	163.		2.
CO2 CONCENTRATION PCT	1.4038		.8833	1.1987		.8590
NOX CONCENTRATION PPM	22.7		.3	1.2		.6
THC MASS GRAMS	3.44		.19	1.23		.05
CO MASS GRAMS	26.71		1.57	13.62		.32
CO2 MASS GRAMS	1845.8		1986.8	1579.2		1946.2
NOX MASS GRAMS	2.78		.06	.15		.13
THC GRAMS/MI	.96		.05	.34		.01
CO GRAMS/MI	7.43		.41	3.79		.08
CO2 GRAMS/MI	513.6		514.5	440.1		503.1
NOX GRAMS/MI	.77		.01	.04		.03
FUEL ECONOMY IN MPG	16.79	17.00	17.21	19.83	18.62	17.62
RUN TIME SECONDS	505.		867.	506.		867.
MEASURED DISTANCE MI	3.59	7.46	3.86	3.59	7.46	3.87
SCF, DRY	.977	.980	.982	.979	.981	.982
DFC, WET (DRY)		.915(.906)			.922(.913)	
TOT VOL (SCM) / SAM BLR (SCM)		194.7/ .00			195.7/ .00	

COMPOSITE RESULTS

TEST NUMBER		2
BAROMETER	MM HG	743.2
HUMIDITY	G/KG	7.0
TEMPERATURE	DEG C	27.2

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	493.9	(490.5)
FUEL ECONOMY	MPG	17.76	(17.89)
HYDROCARBONS (THC)	G/MI	.32	(.31)
CARBON MONOXIDE	G/MI	2.79	(2.70)
OXIDES OF NITROGEN	G/MI	.18	(.19)

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TEST NO. 3 RUN 1	VEHICLE NO.CP1	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/23/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 2007. KM(1247. MILES)
BAROMETER 746.00 MM HG(29.37 IN HG)	DRY BULB TEMP. 22.2 DEG C(72.0 DEG F)	
RELATIVE HUMIDITY 46. PCT	ABS. HUMIDITY 7.8 GM/KG	NOX HUMIDITY CORRECTION FACTOR .91

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		40.6 (105.0)	41.1 (106.0)		39.4 (103.0)
BLOWER REVOLUTIONS	40262.		68956.	40109.		68805.
TOT FLOW STD. CU. METRES(SCF)	72.7 (2568.)		125.7 (4438.)	73.0 (2577.)		125.9 (4445.)
THC SAMPLE METER/RANGE/PPM	9.8/ 3/ 98.		8.5/ 2/ 8.	20.1/ 2/ 20.		8.1/ 2/ 8.
THC BCKGRD METER/RANGE/PPM	1.0/ 3/ 10.		7.6/ 2/ 8.	6.1/ 2/ 6.		6.1/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	91.4/ 14/ 453.		9.3/ 12/ 9.	48.8/ 13/ 114.		25.5/ 12/ 25.
CO BCKGRD METER/RANGE/PPM	.3/ 14/ 1.		.0/ 12/ 0.	.5/ 13/ 1.		1.0/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	67.9/ 1/1.2557		90.4/ 14/ .8768	64.1/ 1/1.1862		89.8/ 14/ .8623
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0437		13.0/ 14/ .0438	2.4/ 1/ .0420		13.0/ 14/ .0438
NOX SAMPLE METER/RANGE/PPM	68.9/ 1/ 17.3		4.2/ 1/ 1.1	8.3/ 1/ 2.2		2.0/ 1/ .5
NOX BCKGRD METER/RANGE/PPM	.8/ 1/ .2		.6/ 1/ .2	.7/ 1/ .2		.7/ 1/ .2
DILUTION FACTOR	10.24		15.25	11.17		15.48
THC CONCENTRATION PPM	89.		1.	15.		2.
CO CONCENTRATION PPM	435.		9.	109.		24.
CO2 CONCENTRATION PCT	1.2163		.8358	1.1480		.8213
NOX CONCENTRATION PPM	17.1		1.0	2.0		.4
THC MASS GRAMS	3.72		.10	.61		.17
CO MASS GRAMS	36.81		1.33	9.23		3.47
CO2 MASS GRAMS	1619.3		1923.5	1533.7		1892.8
NOX MASS GRAMS	2.17		.21	.25		.08
THC GRAMS/MI	1.03		.03	.17		.04
CO GRAMS/MI	10.21		.34	2.57		.90
CO2 GRAMS/MI	449.3		497.8	426.2		488.8
NOX GRAMS/MI	.60		.05	.07		.02
FUEL ECONOMY IN MPG	18.92	18.32	17.79	20.58	19.21	18.09
RUN TIME SECONDS	505.		867.	505.		867.
MEASURED DISTANCE MI	3.60	7.47	3.86	3.60	7.47	3.87
SCF, DRY	.974	.976	.977	.974	.976	.977
DFC, WET (DRY)		.923(.909)			.926(.913)	
TOT VOL (SCM) / SAM BLR (SCM)		198.4/ .00			198.8/ .00	

COMPOSITE RESULTS

TEST NUMBER		3
BAROMETER	MM HG	746.0
HUMIDITY	G/KG	7.8
TEMPERATURE	DEG C	22.2

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	468.1	(465.4)
FUEL ECONOMY	MPG	18.72	(18.82)
HYDROCARBONS (THC)	G/MI	.27	(.28)
CARBON MONOXIDE	G/MI	3.00	(3.17)
OXIDES OF NITROGEN	G/MI	.17	(.16)

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TEST NO. 3 RUN 1	VEHICLE NO.CP2	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/23/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 1893. KM(1176. MILES)

BAROMETER 746.76 MM HG(29.40 IN HG) DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
RELATIVE HUMIDITY 38. PCT ABS. HUMIDITY 7.1 GM/KG NOX HUMIDITY CORRECTION FACTOR .89

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H20(IN. H20)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H20(IN. H20)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	42.8 (109.0)		39.4 (103.0)	42.2 (108.0)		40.0 (104.0)
BLOWER REVOLUTIONS	40127.		68774.	40065.		68751.
TOT FLOW STD. CU. METRES(SCF)	72.7 (2566.)		126.0 (4448.)	72.7 (2567.)		125.7 (4438.)
THC SAMPLE METER/RANGE/PPM	85.8/ 2/ 86.		23.4/ 2/ 23.	41.9/ 2/ 42.		21.0/ 2/ 21.
THC BCKGRD METER/RANGE/PPM	6.5/ 2/ 6.		10.2/ 2/ 10.	9.8/ 2/ 10.		9.4/ 2/ 9.
CO SAMPLE METER/RANGE/PPM	61.2/ 14/ 281.		55.7/ 12/ 55.	60.3/ 13/ 143.		53.5/ 12/ 53.
CO BCKGRD METER/RANGE/PPM	.4/ 14/ 2.		.8/ 12/ 1.	.3/ 13/ 1.		.5/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	75.4/ 1/1.3936		91.0/ 14/ .8915	65.8/ 1/1.2173		90.5/ 14/ .8792
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0420		13.0/ 14/ .0438	2.4/ 1/ .0420		13.0/ 14/ .0438
NOX SAMPLE METER/RANGE/PPM	77.2/ 1/ 19.3		.6/ 1/ .2	2.4/ 1/ .6		.6/ 1/ .2
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .1		.4/ 1/ .1	.3/ 1/ .1		.2/ 1/ .1
DILUTION FACTOR	9.38		14.90	10.85		15.12
THC CONCENTRATION PPM	80.		14.	33.		12.
CO CONCENTRATION PPM	268.		53.	137.		51.
CO2 CONCENTRATION PCT	1.3561		.8507	1.1792		.8383
NOX CONCENTRATION PPM	19.2		.1	.6		.1
THC MASS GRAMS	3.35		1.01	1.38		.89
CO MASS GRAMS	22.71		7.78	11.60		7.50
CO2 MASS GRAMS	1804.6		1961.8	1569.5		1929.0
NOX MASS GRAMS	2.39		.01	.07		.02
THC GRAMS/MI	.93		.26	.38		.23
CO GRAMS/MI	6.31		2.01	3.21		1.93
CO2 GRAMS/MI	500.9		505.8	434.6		497.6
NOX GRAMS/MI	.66		.00	.02		.01
FUEL ECONOMY IN MPG	17.26	17.33	17.39	20.11	18.78	17.69
RUN TIME SECONDS	505.		867.	505.		867.
MEASURED DISTANCE MI	3.60	7.48	3.88	3.61	7.49	3.88
SCF, DRY	.975	.978	.980	.977	.979	.980
DFC, WET (DRY)		.918(.907)			.924(.913)	
TOT VOL (SCM) / SAM BLR (SCM)		198.7/ .00			198.4/ .00	

COMPOSITE RESULTS

TEST NUMBER		3
BAROMETER	MM HG	746.8
HUMIDITY	G/KG	7.1
TEMPERATURE	DEG C	23.9

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	485.2	(482.8)
FUEL ECONOMY	MPG	18.04	(18.13)
HYDROCARBONS (THC)	G/MI	.43	(.42)
CARBON MONOXIDE	G/MI	3.23	(3.21)
OXIDES OF NITROGEN	G/MI	.14	(.14)

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TEST NO. 3 RUN 1	VEHICLE NO.CP3	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 2/23/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 2211. KM(1374. MILES)
BAROMETER 742.95 MM HG(29.25 IN HG)	DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)	
RELATIVE HUMIDITY 29. PCT	ABS. HUMIDITY 6.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR .87

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		40.6 (105.0)	41.1 (106.0)		41.1 (106.0)
BLOWER REVOLUTIONS	40137.		68823.	40034.		68697.
TOT FLOW STD. CU. METRES(SCF)	72.1 (2547.)		124.8 (4408.)	72.5 (2560.)		124.4 (4392.)
THC SAMPLE METER/RANGE/PPM	83.3/ 2/ 83.		8.6/ 2/ 9.	24.3/ 2/ 24.		7.1/ 2/ 7.
THC BCKGRD METER/RANGE/PPM	9.0/ 2/ 9.		8.5/ 2/ 8.	6.8/ 2/ 7.		6.5/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	75.4/ 14/ 360.		5.7/ 12/ 6.	43.4/ 13/ 101.		3.3/ 12/ 3.
CO BCKGRD METER/RANGE/PPM	.4/ 14/ 2.		.4/ 12/ 0.	.0/ 13/ 0.		.1/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	76.9/ 1/1.4214		91.9/ 14/ .9142	67.8/ 1/1.2539		91.4/ 14/ .9015
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0455		12.9/ 14/ .0434	2.4/ 1/ .0420		12.3/ 14/ .0411
NOX SAMPLE METER/RANGE/PPM	77.7/ 1/ 19.5		1.7/ 1/ .4	10.0/ 1/ 2.6		5.4/ 1/ 1.4
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ .1		.4/ 1/ .1	.6/ 1/ .2		.5/ 1/ .1
DILUTION FACTOR	9.15		14.63	10.58		14.85
THC CONCENTRATION PPM	75.		1.	18.		1.
CO CONCENTRATION PPM	346.		5.	97.		3.
CO2 CONCENTRATION PCT	1.3809		.8738	1.2159		.8632
NOX CONCENTRATION PPM	19.4		.4	2.4		1.3
THC MASS GRAMS	3.13		.05	.76		.07
CO MASS GRAMS	29.02		.76	8.23		.46
CO2 MASS GRAMS	1823.7		1997.2	1613.8		1965.5
NOX MASS GRAMS	2.33		.07	.30		.27
THC GRAMS/MI	.87		.01	.21		.02
CO GRAMS/MI	8.05		.20	2.29		.12
CO2 GRAMS/MI	506.1		515.9	449.2		509.2
NOX GRAMS/MI	.65		.02	.08		.07
FUEL ECONOMY IN MPG	17.00	17.09	17.18	19.55	18.38	17.41
RUN TIME SECONDS	505.		867.	504.		867.
MEASURED DISTANCE MI	3.60	7.47	3.87	3.59	7.45	3.86
SCF, DRY	.978	.981	.982	.979	.981	.982
DFC, WET (DRY)		.917(.908)			.923(.914)	
TOT VOL (SCM) / SAM BLR (SCM)		197.0/ .00			196.9/ .00	

COMPOSITE RESULTS

TEST NUMBER		3
BAROMETER	MM HG	743.0
HUMIDITY	G/KG	6.2
TEMPERATURE	DEG C	26.1

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	495.6	(493.6)
FUEL ECONOMY	MPG	17.73	(17.80)
HYDROCARBONS (THC)	G/MI	.24	(.25)
CARBON MONOXIDE	G/MI	2.40	(2.38)
OXIDES OF NITROGEN	G/MI	.17	(.18)

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TEST NO. 4 RUN 1	VEHICLE NO.CP1	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/ 3/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 8484. KM(5272. MILES)
BAROMETER 738.89 MM HG(29.09 IN HG)	DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)	
RELATIVE HUMIDITY 30. PCT	ABS. HUMIDITY 5.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR .85

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1041.4 (41.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1092.2 (43.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.7 (107.0)		39.4 (103.0)	42.2 (108.0)		38.9 (102.0)
BLOWER REVOLUTIONS	40386.		69095.	40219.		69011.
TOT FLOW STD. CU. METRES(SCF)	72.5 (2562.)		125.0 (4415.)	72.4 (2555.)		125.1 (4417.)
THC SAMPLE METER/RANGE/PPM	12.1/ 3/ 121.		7.5/ 2/ 7.	39.4/ 2/ 39.		7.7/ 2/ 8.
THC BCKGRD METER/RANGE/PPM	.7/ 3/ 7.		6.0/ 2/ 6.	6.6/ 2/ 7.		6.0/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	63.2/ 1/ 571.		15.4/ 12/ 15.	48.7/ 14/ 216.		24.4/ 12/ 24.
CO BCKGRD METER/RANGE/PPM	.0/ 1/ 0.		.0/ 12/ 0.	.2/ 14/ 1.		.5/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	75.1/ 1/1.3881		90.9/ 14/ .8890	66.1/ 1/1.2228		91.1/ 14/ .8940
CO2 BCKGRD METER/RANGE/PCT	2.3/ 1/ .0402		12.1/ 14/ .0403	2.1/ 1/ .0367		12.4/ 14/ .0415
NOX SAMPLE METER/RANGE/PPM	89.3/ 1/ 22.3		3.0/ 1/ .8	7.1/ 1/ 1.9		1.6/ 1/ .4
NOX BCKGRD METER/RANGE/PPM	.3/ 1/ .1		.2/ 1/ .1	.0/ 1/ .0		.1/ 1/ .0
DILUTION FACTOR	9.21		15.03	10.74		14.94
THC CONCENTRATION PPM	114.		2.	33.		2.
CO CONCENTRATION PPM	550.		15.	208.		23.
CO2 CONCENTRATION PCT	1.3522		.8514	1.1895		.8553
NOX CONCENTRATION PPM	22.3		.7	1.9		.4
THC MASS GRAMS	4.79		.14	1.39		.15
CO MASS GRAMS	46.45		2.19	17.49		3.38
CO2 MASS GRAMS	1796.1		1949.1	1576.0		1959.1
NOX MASS GRAMS	2.62		.15	.22		.08
THC GRAMS/MI	1.32		.04	.39		.04
CO GRAMS/MI	12.84		.57	4.86		.87
CO2 GRAMS/MI	496.4		506.9	437.9		504.0
NOX GRAMS/MI	.72		.04	.06		.02
FUEL ECONOMY IN MPG	17.03	17.25	17.46	19.85	18.58	17.54
RUN TIME SECONDS	506.		868.	506.		869.
MEASURED DISTANCE MI	3.62	7.46	3.85	3.60	7.49	3.89
SCF, DRY	.978	.981	.982	.979	.981	.982
DFC, WET (DRY)		.918(.909)			.923(.915)	
TOT VOL (SCM) / SAM BLR (SCM)		197.6/ .00			197.5/ .00	

COMPOSITE RESULTS

TEST NUMBER		4
BAROMETER	MM HG	738.9
HUMIDITY	G/KG	5.2
TEMPERATURE	DEG C	22.8

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	485.7	(484.9)
FUEL ECONOMY	MPG	17.96	(17.98)
HYDROCARBONS (THC)	G/MI	.40	(.40)
CARBON MONOXIDE	G/MI	4.31	(4.39)
OXIDES OF NITROGEN	G/MI	.19	(.18)

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TEST NO. 4 RUN 1	VEHICLE NO.CP2	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/ 3/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 7992. KM(4966. MILES)

BAROMETER 740.16 MM HG(29.14 IN HG)	DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)	
RELATIVE HUMIDITY 27. PCT	ABS. HUMIDITY 5.5 GM/KG	NOX HUMIDITY CORRECTION FACTOR .85

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.7 (107.0)		39.4 (103.0)	40.6 (105.0)		39.4 (103.0)
BLOWER REVOLUTIONS	39868.		67938.	39966.		68610.
TOT FLOW STD. CU. METRES(SCF)	71.7 (2532.)		123.1 (4345.)	72.2 (2548.)		124.4 (4391.)
THC SAMPLE METER/RANGE/PPM	91.1/ 2/ 91.		13.0/ 2/ 13.	73.1/ 2/ 73.		12.6/ 2/ 13.
THC BCKGRD METER/RANGE/PPM	6.1/ 2/ 6.		6.1/ 2/ 6.	6.2/ 2/ 6.		6.3/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	69.7/ 14/ 328.		34.6/ 12/ 34.	79.3/ 14/ 383.		39.9/ 12/ 40.
CO BCKGRD METER/RANGE/PPM	.0/ 14/ 0.		.0/ 12/ 0.	.2/ 14/ 1.		.0/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	75.2/ 1/1.3899		92.4/ 14/ .9271	63.1/ 1/1.1679		89.7/ 14/ .8599
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0420		12.4/ 14/ .0415	2.6/ 1/ .0455		12.5/ 14/ .0418
NOX SAMPLE METER/RANGE/PPM	68.3/ 1/ 17.1		.3/ 1/ .1	1.1/ 1/ .3		.5/ 1/ .1
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ .1		.1/ 1/ .0	.4/ 1/ .1		.4/ 1/ .1
DILUTION FACTOR	9.37		14.38	11.05		15.49
THC CONCENTRATION PPM	86.		7.	67.		7.
CO CONCENTRATION PPM	316.		34.	370.		39.
CO2 CONCENTRATION PCT	1.3524		.8885	1.1265		.8208
NOX CONCENTRATION PPM	17.0		.1	.2		.0
THC MASS GRAMS	3.54		.52	2.81		.48
CO MASS GRAMS	26.39		4.80	31.09		5.60
CO2 MASS GRAMS	1775.5		2001.7	1488.5		1868.7
NOX MASS GRAMS	1.99		.01	.02		.01
THC GRAMS/MI	.98		.13	.78		.12
CO GRAMS/MI	7.32		1.24	8.68		1.45
CO2 GRAMS/MI	492.7		517.5	415.3		484.8
NOX GRAMS/MI	.55		.00	.01		.00
FUEL ECONOMY IN MPG	17.48	17.26	17.06	20.56	19.26	18.19
RUN TIME SECONDS	506.		868.	505.		867.
MEASURED DISTANCE MI	3.60	7.47	3.87	3.58	7.44	3.85
SCF, DRY	.978	.981	.983	.980	.982	.983
DFC, WET (DRY)		.917(.909)			.926(.918)	
TOT VOL (SCM) / SAM BLR (SCM)		194.8/ .00			196.5/ .00	

COMPOSITE RESULTS

TEST NUMBER		4
BAROMETER	MM HG	740.2
HUMIDITY	G/KG	5.5
TEMPERATURE	DEG C	25.0

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	484.3	(474.6)
FUEL ECONOMY	MPG	17.99	(18.34)
HYDROCARBONS (THC)	G/MI	.49	(.49)
CARBON MONOXIDE	G/MI	4.54	(4.61)
OXIDES OF NITROGEN	G/MI	.12	(.12)

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TEST NO. 4 RUN 1	VEHICLE NO.CP3	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/ 3/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 8700. KM(5406. MILES)

BAROMETER 740.92 MM HG(29.17 IN HG)	DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)	
RELATIVE HUMIDITY 24. PCT	ABS. HUMIDITY 4.8 GM/KG	NOX HUMIDITY CORRECTION FACTOR .84

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	40.0 (104.0)		39.4 (103.0)	40.6 (105.0)		39.4 (103.0)
BLOWER REVOLUTIONS	40074.		68672.	40038.		68665.
TOT FLOW STD. CU. METRES(SCF)	72.6 (2563.)		124.6 (4400.)	72.4 (2556.)		124.6 (4400.)
THC SAMPLE METER/RANGE/PPM	97.3/ 2/ 97.		7.5/ 2/ 7.	43.8/ 2/ 44.		8.2/ 2/ 8.
THC BCKGRD METER/RANGE/PPM	5.6/ 2/ 6.		5.6/ 2/ 6.	6.0/ 2/ 6.		5.8/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	75.7/ 14/ 362.		14.2/ 12/ 14.	48.2/ 14/ 213.		14.4/ 12/ 14.
CO BCKGRD METER/RANGE/PPM	.1/ 14/ 0.		.1/ 12/ 0.	.0/ 14/ 0.		.0/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	74.8/ 1/1.3825		91.4/ 14/ .9015	65.2/ 1/1.2063		90.5/ 14/ .8792
CO2 BCKGRD METER/RANGE/PCT	2.2/ 1/ .0384		12.4/ 14/ .0415	2.3/ 1/ .0402		12.0/ 14/ .0399
NOX SAMPLE METER/RANGE/PPM	81.6/ 1/ 20.4		1.7/ 1/ .4	5.8/ 1/ 1.5		3.6/ 1/ .9
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ .0		.0/ 1/ .0	.0/ 1/ .0		.0/ 1/ .0
DILUTION FACTOR	9.39		14.83	10.88		15.20
THC CONCENTRATION PPM	92.		2.	38.		3.
CO CONCENTRATION PPM	349.		14.	206.		14.
CO2 CONCENTRATION PCT	1.3482		.8629	1.1698		.8419
NOX CONCENTRATION PPM	20.4		.4	1.5		.9
THC MASS GRAMS	3.86		.16	1.60		.20
CO MASS GRAMS	29.50		2.00	17.39		2.04
CO2 MASS GRAMS	1791.7		1968.7	1550.4		1920.8
NOX MASS GRAMS	2.38		.09	.18		.19
THC GRAMS/MI	1.08		.04	.45		.05
CO GRAMS/MI	8.23		.52	4.85		.53
CO2 GRAMS/MI	499.9		512.6	432.5		500.1
NOX GRAMS/MI	.66		.02	.05		.05
FUEL ECONOMY IN MPG	17.18	17.22	17.27	20.09	18.77	17.70
RUN TIME SECONDS	506.		868.	505.		868.
MEASURED DISTANCE MI	3.58	7.42	3.84	3.59	7.43	3.84
SCF, DRY	.979	.982	.984	.981	.983	.984
DFC, WET (DRY)		.918(.911)			.925(.917)	
TOT VOL (SCM) / SAM BLR (SCM)		197.2/ .00			197.0/ .00	

COMPOSITE RESULTS

TEST NUMBER		4
BAROMETER	MM HG	740.9
HUMIDITY	G/KG	4.8
TEMPERATURE	DEG C	25.0

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	487.9	(484.2)
FUEL ECONOMY	MPG	17.94	(18.07)
HYDROCARBONS (THC)	G/MI	.37	(.37)
CARBON MONOXIDE	G/MI	3.31	(3.32)
OXIDES OF NITROGEN	G/MI	.16	(.17)

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TEST NO. 5 RUN 1	VEHICLE NO.CP1	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/11/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 16367. KM(10170. MILES)

BAROMETER 742.19 MM HG(29.22 IN HG)	DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)	
RELATIVE HUMIDITY 46. PCT	ABS. HUMIDITY 9.3 GM/KG	NOX HUMIDITY CORRECTION FACTOR .95

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		39.4 (103.0)	42.8 (109.0)		42.2 (108.0)
BLOWER REVOLUTIONS	40243.		68962.	40183.		68766.
TOT FLOW STD. CU. METRES(SCF)	72.3 (2551.)		125.4 (4429.)	72.3 (2552.)		123.9 (4375.)
THC SAMPLE METER/RANGE/PPM	85.2/ 2/ 85.		7.3/ 2/ 7.	57.3/ 2/ 57.		6.9/ 2/ 7.
THC BCKGRD METER/RANGE/PPM	6.1/ 2/ 6.		6.1/ 2/ 6.	6.1/ 2/ 6.		6.0/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	84.1/ 14/ 411.		23.4/ 12/ 23.	81.8/ 14/ 397.		18.5/ 12/ 19.
CO BCKGRD METER/RANGE/PPM	.2/ 14/ 1.		.2/ 12/ 0.	.0/ 14/ 0.		.0/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	74.5/ 1/1.3770		91.4/ 14/ .9015	64.5/ 1/1.1935		91.0/ 14/ .8915
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0420		12.4/ 14/ .0415	2.6/ 1/ .0455		12.1/ 14/ .0403
NOX SAMPLE METER/RANGE/PPM	94.6/ 1/ 23.6		2.2/ 1/ .6	5.0/ 1/ 1.3		2.4/ 1/ .6
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .1		.4/ 1/ .1	.5/ 1/ .1		.6/ 1/ .2
DILUTION FACTOR	9.40		14.81	10.83		14.99
THC CONCENTRATION PPM	80.		2.	52.		1.
CO CONCENTRATION PPM	393.		22.	382.		18.
CO2 CONCENTRATION PCT	1.3395		.8629	1.1522		.8539
NOX CONCENTRATION PPM	23.5		.5	1.2		.5
THC MASS GRAMS	3.32		.12	2.16		.09
CO MASS GRAMS	33.06		3.27	32.17		2.58
CO2 MASS GRAMS	1771.9		1981.6	1524.6		1936.9
NOX MASS GRAMS	3.10		.11	.16		.11
THC GRAMS/MI	.91		.03	.60		.02
CO GRAMS/MI	9.06		.85	8.93		.67
CO2 GRAMS/MI	485.6		515.4	423.2		499.6
NOX GRAMS/MI	.85		.03	.04		.03
FUEL ECONOMY IN MPG	17.64	17.39	17.16	20.19	18.82	17.71
RUN TIME SECONDS	505.		867.	505.		867.
MEASURED DISTANCE MI	3.65	7.49	3.85	3.60	7.48	3.88
SCF, DRY	.972	.975	.977	.974	.976	.977
DFC, WET (DRY)		.918(.905)			.924(.910)	
TOT VOL (SCM) / SAM BLR (SCM)		197.7/ .00			196.2/ .00	

COMPOSITE RESULTS

TEST NUMBER		5
BAROMETER	MM HG	742.2
HUMIDITY	G/KG	9.3
TEMPERATURE	DEG C	25.0

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	483.7	(479.2)
FUEL ECONOMY	MPG	18.01	(18.18)
HYDROCARBONS (THC)	G/MI	.37	(.37)
CARBON MONOXIDE	G/MI	4.80	(4.73)
OXIDES OF NITROGEN	G/MI	.20	(.20)

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TEST NO. 5 RUN 1	VEHICLE NO.CP2	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/11/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 16262. KM(10105. MILES)
BAROMETER 741.68 MM HG(29.20 IN HG)	DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)	
RELATIVE HUMIDITY 48. PCT	ABS. HUMIDITY 9.5 GM/KG	NOX HUMIDITY CORRECTION FACTOR .96

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H20(IN. H20)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H20(IN. H20)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	42.2 (108.0)		41.7 (107.0)	43.3 (110.0)		41.7 (107.0)
BLOWER REVOLUTIONS	40132.		68839.	40116.		68854.
TOT FLOW STD. CU. METRES(SCF)	72.3 (2551.)		124.2 (4384.)	72.0 (2541.)		124.2 (4385.)
THC SAMPLE METER/RANGE/PPM	91.3/ 2/ 91.		8.8/ 2/ 9.	58.8/ 2/ 59.		9.7/ 2/ 10.
THC BCKGRD METER/RANGE/PPM	5.6/ 2/ 6.		5.5/ 2/ 5.	5.3/ 2/ 5.		5.6/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	70.8/ 14/ 334.		31.9/ 12/ 32.	60.5/ 14/ 277.		24.9/ 12/ 25.
CO BCKGRD METER/RANGE/PPM	.1/ 14/ 0.		.2/ 12/ 0.	.0/ 14/ 0.		.1/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	75.1/ 1/1.3881		90.4/ 14/ .8768	64.1/ 1/1.1862		89.4/ 14/ .8528
CO2 BCKGRD METER/RANGE/PCT	2.2/ 1/ .0384		11.8/ 14/ .0391	2.5/ 1/ .0437		11.8/ 14/ .0391
NOX SAMPLE METER/RANGE/PPM	70.6/ 1/ 17.7		.7/ 1/ .2	3.0/ 1/ .8		.9/ 1/ .2
NOX BCKGRD METER/RANGE/PPM	.0/ 1/ .0		.1/ 1/ .0	.3/ 1/ .1		.4/ 1/ .1
DILUTION FACTOR	9.38		15.21	11.00		15.65
THC CONCENTRATION PPM	86.		4.	54.		4.
CO CONCENTRATION PPM	319.		31.	266.		24.
CO2 CONCENTRATION PCT	1.3537		.8402	1.1464		.8161
NOX CONCENTRATION PPM	17.7		.2	.7		.1
THC MASS GRAMS	3.59		.26	2.24		.32
CO MASS GRAMS	26.87		4.41	22.31		3.46
CO2 MASS GRAMS	1790.8		1910.0	1510.3		1855.7
NOX MASS GRAMS	2.35		.04	.10		.03
THC GRAMS/MI	.99		.07	.62		.08
CO GRAMS/MI	7.43		1.13	6.19		.89
CO2 GRAMS/MI	494.9		490.5	419.2		476.5
NOX GRAMS/MI	.65		.01	.03		.01
FUEL ECONOMY IN MPG	17.40	17.71	18.01	20.58	19.47	18.55
RUN TIME SECONDS	505.		867.	505.		868.
MEASURED DISTANCE MI	3.62	7.51	3.89	3.60	7.50	3.89
SCF, DRY	.972	.974	.976	.973	.975	.976
DFC, WET (DRY)		.919(.905)			.926(.912)	
TOT VOL (SCM) / SAM BLR (SCM)		196.4/ .00			196.1/ .00	

COMPOSITE RESULTS

TEST NUMBER		5
BAROMETER	MM HG	741.7
HUMIDITY	G/KG	9.5
TEMPERATURE	DEG C	24.4

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	471.9	(467.7)
FUEL ECONOMY	MPG	18.51	(18.67)
HYDROCARBONS (THC)	G/MI	.41	(.42)
CARBON MONOXIDE	G/MI	3.82	(3.75)
OXIDES OF NITROGEN	G/MI	.15	(.15)

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TEST NO. 5 RUN 1	VEHICLE NO.CP3	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/11/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 16583. KM(10304. MILES)
BAROMETER 741.17 MM HG(29.18 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 46. PCT	ABS. HUMIDITY 9.7 GM/KG	NOX HUMIDITY CORRECTION FACTOR .97

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	43.3 (110.0)		41.7 (107.0)	43.3 (110.0)		42.2 (108.0)
BLOWER REVOLUTIONS	40150.		68861.	40111.		68854.
TOT FLOW STD. CU. METRES(SCF)	72.0 (2541.)		124.1 (4382.)	71.9 (2538.)		123.9 (4374.)
THC SAMPLE METER/RANGE/PPM	92.7/ 2/ 93.		7.6/ 2/ 8.	67.3/ 2/ 67.		7.6/ 2/ 8.
THC BCKGRD METER/RANGE/PPM	8.1/ 2/ 8.		6.4/ 2/ 6.	6.1/ 2/ 6.		6.0/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	78.8/ 14/ 380.		17.7/ 12/ 18.	97.6/ 14/ 489.		18.3/ 12/ 18.
CO BCKGRD METER/RANGE/PPM	1.5/ 14/ 6.		3.5/ 12/ 4.	.4/ 14/ 2.		1.2/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	78.0/ 1/1.4418		91.6/ 14/ .9066	65.3/ 1/1.2081		91.5/ 14/ .9040
CO2 BCKGRD METER/RANGE/PCT	3.8/ 1/ .0667		12.3/ 14/ .0411	2.3/ 1/ .0402		11.8/ 14/ .0391
NOX SAMPLE METER/RANGE/PPM	68.7/ 1/ 17.2		2.2/ 1/ .6	2.4/ 1/ .6		1.5/ 1/ .4
NOX BCKGRD METER/RANGE/PPM	.2/ 1/ .1		.0/ 1/ .0	.0/ 1/ .0		.2/ 1/ .1
DILUTION FACTOR	9.01		14.74	10.62		14.78
THC CONCENTRATION PPM	85.		2.	62.		2.
CO CONCENTRATION PPM	358.		14.	469.		17.
CO2 CONCENTRATION PCT	1.3825		.8683	1.1717		.8675
NOX CONCENTRATION PPM	17.2		.6	.6		.3
THC MASS GRAMS	3.55		.12	2.56		.14
CO MASS GRAMS	30.02		2.01	39.28		2.39
CO2 MASS GRAMS	1821.4		1972.9	1542.2		1967.3
NOX MASS GRAMS	2.29		.13	.08		.08
THC GRAMS/MI	.98		.03	.71		.04
CO GRAMS/MI	8.27		.52	10.89		.61
CO2 GRAMS/MI	502.0		509.8	427.4		504.7
NOX GRAMS/MI	.63		.03	.02		.02
FUEL ECONOMY IN MPG	17.12	17.24	17.36	19.85	18.57	17.53
RUN TIME SECONDS	505.		868.	505.		868.
MEASURED DISTANCE MI	3.63	7.50	3.87	3.61	7.51	3.90
SCF, DRY	.972	.975	.977	.974	.976	.977
DFC, WET (DRY)		.916(.903)			.923(.909)	
TOT VOL (SCM) / SAM BLR (SCM)		196.1/ .00			195.8/ .00	

COMPOSITE RESULTS

TEST NUMBER		5
BAROMETER	MM HG	741.2
HUMIDITY	G/KG	9.7
TEMPERATURE	DEG C	25.6

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	485.5	(484.1)
FUEL ECONOMY	MPG	17.93	(17.98)
HYDROCARBONS (THC)	G/MI	.41	(.42)
CARBON MONOXIDE	G/MI	4.98	(5.00)
OXIDES OF NITROGEN	G/MI	.16	(.15)

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TEST NO. 6 RUN 1
VEHICLE MODEL 91 S-10 PICK UP
ENGINE 4.3 L(262. CID) V-6
TRANSMISSION L4

VEHICLE NO.CP1
DATE 3/19/91
BAG CART NO. 2 / CVS NO. 2
DYNO NO. 3

TEST WEIGHT 1701. KG(3750. LBS)
ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
GASOLINE EM-1198-F
ODOMETER 24420. KM(15174. MILES)

BAROMETER 741.93 MM HG(29.21 IN HG)
RELATIVE HUMIDITY 39. PCT

DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
ABS. HUMIDITY 7.9 GM/KG

NOX HUMIDITY CORRECTION FACTOR .92

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.1 (106.0)		40.6 (105.0)	42.2 (108.0)		41.1 (106.0)
BLOWER REVOLUTIONS	40029.		68726.	40061.		68706.
TOT FLOW STD. CU. METRES(SCF)	72.4 (2555.)		124.5 (4395.)	72.1 (2547.)		124.2 (4385.)
THC SAMPLE METER/RANGE/PPM	14.7/ 3/ 147.		5.7/ 2/ 6.	31.5/ 2/ 31.		6.0/ 2/ 6.
THC BCKGRD METER/RANGE/PPM	.7/ 3/ 7.		4.9/ 2/ 5.	5.7/ 2/ 6.		5.6/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	61.7/ 1/ 553.		12.4/ 12/ 12.	75.6/ 13/ 182.		11.7/ 12/ 12.
CO BCKGRD METER/RANGE/PPM	.0/ 1/ 0.		.4/ 12/ 0.	.0/ 13/ 0.		.1/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	74.1/ 1/1.3696		90.2/ 14/ .8719	64.5/ 1/1.1935		89.6/ 14/ .8575
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0420		12.6/ 14/ .0422	2.5/ 1/ .0437		12.5/ 14/ .0418
NOX SAMPLE METER/RANGE/PPM	74.1/ 1/ 18.6		5.6/ 1/ 1.5	5.9/ 1/ 1.5		4.1/ 1/ 1.1
NOX BCKGRD METER/RANGE/PPM	.0/ 1/ .0		.0/ 1/ .0	.0/ 1/ .0		.0/ 1/ .0
DILUTION FACTOR	9.32		15.34	11.04		15.59
THC CONCENTRATION PPM	140.		1.	26.		1.
CO CONCENTRATION PPM	532.		12.	176.		11.
CO2 CONCENTRATION PCT	1.3321		.8324	1.1537		.8184
NOX CONCENTRATION PPM	18.6		1.5	1.5		1.1
THC MASS GRAMS	5.86		.08	1.09		.05
CO MASS GRAMS	44.78		1.70	14.78		1.64
CO2 MASS GRAMS	1764.8		1896.8	1523.9		1860.7
NOX MASS GRAMS	2.35		.32	.20		.23
THC GRAMS/MI	1.63		.02	.30		.01
CO GRAMS/MI	12.49		.44	4.12		.42
CO2 GRAMS/MI	492.4		490.1	424.7		479.9
NOX GRAMS/MI	.66		.08	.05		.06
FUEL ECONOMY IN MPG	17.15	17.61	18.07	20.52	19.39	18.45
RUN TIME SECONDS	505.		868.	505.		868.
MEASURED DISTANCE MI	3.58	7.45	3.87	3.59	7.47	3.88
SCF, DRY	.975	.978	.979	.976	.978	.979
DFC, WET (DRY)		.919(.908)			.926(.914)	
TOT VOL (SCM) / SAM BLR (SCM)		196.8/ .00			196.3/ .00	

COMPOSITE RESULTS

TEST NUMBER 6
BAROMETER MM HG 741.9
HUMIDITY G/KG 7.9
TEMPERATURE DEG C 25.0

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	472.6	(469.6)
FUEL ECONOMY	MPG	18.47	(18.58)
HYDROCARBONS (THC)	G/MI	.43	(.43)
CARBON MONOXIDE	G/MI	3.94	(3.93)
OXIDES OF NITROGEN	G/MI	.19	(.19)

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TEST NO. 6 RUN 1	VEHICLE NO.CP2	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/19/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 24316. KM(15109. MILES)
BAROMETER 742.19 MM HG(29.22 IN HG)	DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)	
RELATIVE HUMIDITY 48. PCT	ABS. HUMIDITY 9.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR .95

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	40.6 (105.0)		39.4 (103.0)	41.1 (106.0)		40.6 (105.0)
BLOWER REVOLUTIONS	40209.		68914.	40065.		68893.
TOT FLOW STD. CU. METRES(SCF)	72.9 (2573.)		125.3 (4426.)	72.5 (2559.)		124.8 (4408.)
THC SAMPLE METER/RANGE/PPM	95.8/ 2/ 96.		9.1/ 2/ 9.	44.8/ 2/ 45.		7.0/ 2/ 7.
THC BCKGRD METER/RANGE/PPM	6.6/ 2/ 7.		7.2/ 2/ 7.	6.2/ 2/ 6.		5.9/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	50.9/ 1/ 434.		16.8/ 12/ 17.	49.2/ 14/ 218.		10.4/ 12/ 10.
CO BCKGRD METER/RANGE/PPM	.1/ 1/ 1.		.5/ 12/ 1.	.1/ 14/ 0.		.6/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	75.7/ 1/1.3992		90.6/ 14/ .8817	64.9/ 1/1.2008		89.5/ 14/ .8551
CO2 BCKGRD METER/RANGE/PCT	2.6/ 1/ .0455		13.0/ 14/ .0438	2.4/ 1/ .0420		12.8/ 14/ .0430
NOX SAMPLE METER/RANGE/PPM	56.5/ 1/ 14.2		.5/ 1/ .1	1.4/ 1/ .4		.9/ 1/ .2
NOX BCKGRD METER/RANGE/PPM	.3/ 1/ .1		.3/ 1/ .1	.3/ 1/ .1		.4/ 1/ .1
DILUTION FACTOR	9.24		15.16	10.93		15.64
THC CONCENTRATION PPM	90.		2.	39.		1.
CO CONCENTRATION PPM	415.		16.	209.		10.
CO2 CONCENTRATION PCT	1.3586		.8407	1.1627		.8149
NOX CONCENTRATION PPM	14.1		.1	.3		.1
THC MASS GRAMS	3.78		.17	1.64		.11
CO MASS GRAMS	35.20		2.31	17.65		1.39
CO2 MASS GRAMS	1812.5		1929.3	1542.5		1862.4
NOX MASS GRAMS	1.86		.01	.04		.03
THC GRAMS/MI	1.04		.04	.45		.03
CO GRAMS/MI	9.70		.59	4.89		.36
CO2 GRAMS/MI	499.3		493.1	426.9		478.5
NOX GRAMS/MI	.51		.00	.01		.01
FUEL ECONOMY IN MPG	17.12	17.54	17.94	20.34	19.34	18.51
RUN TIME SECONDS	505.		868.	504.		867.
MEASURED DISTANCE MI	3.63	7.54	3.91	3.61	7.50	3.89
SCF, DRY	.972	.975	.976	.973	.975	.977
DFC, WET (DRY)		.918(.904)			.926(.912)	
TOT VOL (SCM) / SAM BLR (SCM)		198.2/ .00			197.3/ .00	

COMPOSITE RESULTS

TEST NUMBER		6
BAROMETER	MM HG	742.2
HUMIDITY	G/KG	9.1
TEMPERATURE	DEG C	23.9

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	476.3	(471.9)
FUEL ECONOMY	MPG	18.35	(18.52)
HYDROCARBONS (THC)	G/MI	.36	(.36)
CARBON MONOXIDE	G/MI	3.65	(3.58)
OXIDES OF NITROGEN	G/MI	.11	(.11)

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TEST NO. 6 RUN 1	VEHICLE NO.CP3	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/19/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 24637. KM(15309. MILES)

BAROMETER 742.44 MM HG(29.23 IN HG)	DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)	
RELATIVE HUMIDITY 39. PCT	ABS. HUMIDITY 7.9 GM/KG	NOX HUMIDITY CORRECTION FACTOR .92

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.7 (107.0)		40.6 (105.0)	41.7 (107.0)		40.6 (105.0)
BLOWER REVOLUTIONS	40084.		68811.	40069.		68773.
TOT FLOW STD. CU. METRES(SCF)	72.4 (2556.)		124.7 (4404.)	72.4 (2555.)		124.6 (4401.)
THC SAMPLE METER/RANGE/PPM	92.8/ 2/ 93.		7.2/ 2/ 7.	56.3/ 2/ 56.		7.1/ 2/ 7.
THC BCKGRD METER/RANGE/PPM	6.0/ 2/ 6.		6.0/ 2/ 6.	6.0/ 2/ 6.		5.9/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	81.0/ 14/ 393.		11.3/ 12/ 11.	68.8/ 14/ 323.		12.3/ 12/ 12.
CO BCKGRD METER/RANGE/PPM	.3/ 14/ 1.		.5/ 12/ 1.	.0/ 14/ 0.		.1/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	76.2/ 1/1.4084		91.3/ 14/ .8990	64.7/ 1/1.1972		90.7/ 14/ .8841
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0437		12.6/ 14/ .0422	2.6/ 1/ .0455		12.5/ 14/ .0418
NOX SAMPLE METER/RANGE/PPM	77.9/ 1/ 19.5		3.3/ 1/ .9	3.3/ 1/ .9		4.6/ 1/ 1.2
NOX BCKGRD METER/RANGE/PPM	.0/ 1/ .0		.2/ 1/ .1	.3/ 1/ .1		.3/ 1/ .1
DILUTION FACTOR	9.21		14.88	10.86		15.12
THC CONCENTRATION PPM	87.		2.	51.		2.
CO CONCENTRATION PPM	376.		11.	311.		12.
CO2 CONCENTRATION PCT	1.3694		.8596	1.1559		.8450
NOX CONCENTRATION PPM	19.5		.8	.8		1.1
THC MASS GRAMS	3.65		.12	2.12		.11
CO MASS GRAMS	31.68		1.53	26.21		1.73
CO2 MASS GRAMS	1814.9		1963.0	1531.2		1928.4
NOX MASS GRAMS	2.48		.18	.10		.25
THC GRAMS/MI	1.01		.03	.59		.03
CO GRAMS/MI	8.73		.39	7.26		.44
CO2 GRAMS/MI	500.3		503.1	424.2		495.2
NOX GRAMS/MI	.68		.05	.03		.06
FUEL ECONOMY IN MPG	17.15	17.38	17.60	20.27	18.96	17.88
RUN TIME SECONDS	505.		867.	505.		868.
MEASURED DISTANCE MI	3.63	7.53	3.90	3.61	7.50	3.89
SCF, DRY	.974	.977	.979	.976	.978	.979
DFC, WET (DRY)		.918(.906)			.924(.913)	
TOT VOL (SCM) / SAM BLR (SCM)		197.1/ .00			197.0/ .00	

COMPOSITE RESULTS

TEST NUMBER		6
BAROMETER	MM HG	742.4
HUMIDITY	G/KG	7.9
TEMPERATURE	DEG C	25.0

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	480.9	(478.5)
FUEL ECONOMY	MPG	18.16	(18.24)
HYDROCARBONS (THC)	G/MI	.38	(.38)
CARBON MONOXIDE	G/MI	4.00	(4.02)
OXIDES OF NITROGEN	G/MI	.17	(.18)

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TEST NO. 7 RUN 1	VEHICLE NO.CP1	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/27/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 32467. KM(20174. MILES)
BAROMETER 736.85 MM HG(29.01 IN HG)	DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)	
RELATIVE HUMIDITY 59. PCT	ABS. HUMIDITY 11.3 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.02

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	42.8 (109.0)		40.6 (105.0)	41.7 (107.0)		39.4 (103.0)
BLOWER REVOLUTIONS	40236.		68992.	40191.		68854.
TOT FLOW STD. CU. METRES(SCF)	71.8 (2534.)		124.0 (4378.)	72.0 (2541.)		124.2 (4385.)
THC SAMPLE METER/RANGE/PPM	10.6/ 3/ 106.		8.3/ 2/ 8.	43.0/ 2/ 43.		6.3/ 2/ 6.
THC BCKGRD METER/RANGE/PPM	.9/ 3/ 9.		7.3/ 2/ 7.	6.3/ 2/ 6.		5.4/ 2/ 5.
CO SAMPLE METER/RANGE/PPM	65.1/ 1/ 593.		12.3/ 12/ 12.	60.9/ 14/ 279.		16.5/ 12/ 17.
CO BCKGRD METER/RANGE/PPM	.0/ 1/ 0.		.6/ 12/ 1.	.0/ 14/ 0.		.2/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	72.8/ 1/1.3457		89.8/ 14/ .8623	63.1/ 1/1.1679		88.9/ 14/ .8411
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0420		12.2/ 14/ .0407	2.5/ 1/ .0437		12.2/ 14/ .0407
NOX SAMPLE METER/RANGE/PPM	80.4/ 1/ 20.1		4.0/ 1/ 1.1	4.7/ 1/ 1.2		3.5/ 1/ .9
NOX BCKGRD METER/RANGE/PPM	.4/ 1/ .1		.2/ 1/ .1	.3/ 1/ .1		.3/ 1/ .1
DILUTION FACTOR	9.48		15.50	11.18		15.89
THC CONCENTRATION PPM	98.		1.	37.		1.
CO CONCENTRATION PPM	567.		11.	268.		16.
CO2 CONCENTRATION PCT	1.3081		.8242	1.1281		.8030
NOX CONCENTRATION PPM	20.0		1.0	1.2		.8
THC MASS GRAMS	4.04		.11	1.55		.09
CO MASS GRAMS	47.34		1.64	22.42		2.28
CO2 MASS GRAMS	1718.9		1870.9	1486.0		1825.5
NOX MASS GRAMS	2.80		.24	.16		.20
THC GRAMS/MI	1.12		.03	.43		.02
CO GRAMS/MI	13.16		.42	6.25		.59
CO2 GRAMS/MI	478.0		483.4	414.1		473.6
NOX GRAMS/MI	.78		.06	.05		.05
FUEL ECONOMY IN MPG	17.65	17.99	18.31	20.85	19.67	18.68
RUN TIME SECONDS	505.		868.	506.		868.
MEASURED DISTANCE MI	3.60	7.47	3.87	3.59	7.44	3.85
SCF, DRY	.969	.971	.973	.970	.972	.973
DFC, WET (DRY)		.920(.903)			.927(.910)	
TOT VOL (SCM) / SAM BLR (SCM)		195.8/ .00			196.1/ .00	

COMPOSITE RESULTS

TEST NUMBER		7			3-BAG	(4-BAG)
BAROMETER	MM HG	736.9	CARBON DIOXIDE	G/MI	463.3	(460.4)
HUMIDITY	G/KG	11.3	FUEL ECONOMY	MPG	18.80	(18.91)
TEMPERATURE	DEG C	23.9	HYDROCARBONS (THC)	G/MI	.37	(.36)
			CARBON MONOXIDE	G/MI	4.66	(4.71)
			OXIDES OF NITROGEN	G/MI	.21	(.20)

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TEST NO. 7 RUN 1
VEHICLE MODEL 91 S-10 PICK UP
ENGINE 4.3 L(262. CID) V-6
TRANSMISSION L4

VEHICLE NO.CP2
DATE 3/27/91
BAG CART NO. 2 / CVS NO. 2
DYNO NO. 3

TEST WEIGHT 1701. KG(3750. LBS)
ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
GASOLINE EM-1198-F
ODOMETER 32362. KM(20109. MILES)

BAROMETER 738.12 MM HG(29.06 IN HG)
RELATIVE HUMIDITY 35. PCT

DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)
ABS. HUMIDITY 6.9 GM/KG

NOX HUMIDITY CORRECTION FACTOR .89

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1016.0 (40.0)		1016.0 (40.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.1 (106.0)		40.6 (105.0)	40.6 (105.0)		38.9 (102.0)
BLOWER REVOLUTIONS	40087.		68809.	40016.		68715.
TOT FLOW STD. CU. METRES(SCF)	72.6 (2563.)		124.8 (4406.)	72.0 (2544.)		124.4 (4392.)
THC SAMPLE METER/RANGE/PPM	10.8/ 3/ 108.		6.9/ 2/ 7.	39.4/ 2/ 39.		7.2/ 2/ 7.
THC BCKGRD METER/RANGE/PPM	.6/ 3/ 6.		5.2/ 2/ 5.	5.3/ 2/ 5.		5.4/ 2/ 5.
CO SAMPLE METER/RANGE/PPM	56.0/ 1/ 489.		8.4/ 12/ 8.	74.8/ 13/ 180.		16.9/ 12/ 17.
CO BCKGRD METER/RANGE/PPM	.4/ 1/ 3.		1.5/ 12/ 2.	.3/ 13/ 1.		.3/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	73.9/ 1/1.3659		89.6/ 14/ .8575	64.4/ 1/1.1917		89.4/ 14/ .8528
CO2 BCKGRD METER/RANGE/PCT	2.4/ 1/ .0420		13.1/ 14/ .0442	2.5/ 1/ .0437		12.4/ 14/ .0415
NOX SAMPLE METER/RANGE/PPM	74.4/ 1/ 18.6		.6/ 1/ .2	2.2/ 1/ .6		.6/ 1/ .2
NOX BCKGRD METER/RANGE/PPM	.0/ 1/ .0		.2/ 1/ .1	.3/ 1/ .1		.4/ 1/ .1
DILUTION FACTOR	9.41		15.60	11.05		15.67
THC CONCENTRATION PPM	102.		2.	35.		2.
CO CONCENTRATION PPM	468.		7.	174.		16.
CO2 CONCENTRATION PCT	1.3284		.8162	1.1519		.8140
NOX CONCENTRATION PPM	18.6		.1	.5		.1
THC MASS GRAMS	4.28		.15	1.44		.15
CO MASS GRAMS	39.54		.99	14.55		2.34
CO2 MASS GRAMS	1765.0		1864.7	1519.1		1853.7
NOX MASS GRAMS	2.30		.02	.06		.01
THC GRAMS/MI	1.19		.04	.40		.04
CO GRAMS/MI	11.01		.26	4.05		.61
CO2 GRAMS/MI	491.6		483.8	423.2		479.4
NOX GRAMS/MI	.64		.01	.02		.00
FUEL ECONOMY IN MPG	17.30	17.81	18.31	20.58	19.42	18.46
RUN TIME SECONDS	505.		868.	505.		868.
MEASURED DISTANCE MI	3.59	7.44	3.85	3.59	7.46	3.87
SCF, DRY	.976	.979	.981	.978	.980	.981
DFC, WET (DRY)		.920(.910)			.926(.916)	
TOT VOL (SCM) / SAM BLR (SCM)		197.4/ .00			196.4/ .00	

COMPOSITE RESULTS

TEST NUMBER		7
BAROMETER	MM HG	738.1
HUMIDITY	G/KG	6.9
TEMPERATURE	DEG C	24.4

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	468.8	(467.5)
FUEL ECONOMY	MPG	18.65	(18.69)
HYDROCARBONS (THC)	G/MI	.38	(.38)
CARBON MONOXIDE	G/MI	3.53	(3.63)
OXIDES OF NITROGEN	G/MI	.14	(.14)

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TEST NO. 7 RUN 1	VEHICLE NO.CP3	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/27/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 32683. KM(20308. MILES)

BAROMETER 738.63 MM HG(29.08 IN HG) DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
RELATIVE HUMIDITY 27. PCT ABS. HUMIDITY 5.5 GM/KG NOX HUMIDITY CORRECTION FACTOR .85

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	41.1 (106.0)		38.9 (102.0)	42.2 (108.0)		40.0 (104.0)
BLOWER REVOLUTIONS	40068.		68710.	39870.		68675.
TOT FLOW STD. CU. METRES(SCF)	72.1 (2544.)		124.5 (4395.)	71.4 (2522.)		123.9 (4377.)
THC SAMPLE METER/RANGE/PPM	11.5/ 3/ 115.		6.7/ 2/ 7.	90.5/ 2/ 90.		9.0/ 2/ 9.
THC BCKGRD METER/RANGE/PPM	.6/ 3/ 6.		4.7/ 2/ 5.	6.3/ 2/ 6.		6.0/ 2/ 6.
CO SAMPLE METER/RANGE/PPM	57.1/ 1/ 501.		10.0/ 12/ 10.	69.4/ 1/ 645.		20.3/ 12/ 20.
CO BCKGRD METER/RANGE/PPM	.1/ 1/ 1.		.0/ 12/ 0.	2.3/ 1/ 16.		.0/ 12/ 0.
CO2 SAMPLE METER/RANGE/PCT	74.9/ 1/1.3844		91.2/ 14/ .8965	64.2/ 1/1.1880		90.2/ 14/ .8719
CO2 BCKGRD METER/RANGE/PCT	2.3/ 1/ .0402		12.4/ 14/ .0415	.0/ 1/ .0000		11.8/ 14/ .0391
NOX SAMPLE METER/RANGE/PPM	89.9/ 1/ 22.5		4.1/ 1/ 1.1	5.8/ 1/ 1.5		4.4/ 1/ 1.2
NOX BCKGRD METER/RANGE/PPM	.0/ 1/ .0		.1/ 1/ .0	.3/ 1/ .1		.3/ 1/ .1
DILUTION FACTOR	9.28		14.92	10.64		15.32
THC CONCENTRATION PPM	109.		2.	85.		3.
CO CONCENTRATION PPM	483.		10.	611.		20.
CO2 CONCENTRATION PCT	1.3485		.8578	1.1880		.8353
NOX CONCENTRATION PPM	22.5		1.1	1.4		1.1
THC MASS GRAMS	4.54		.17	3.49		.24
CO MASS GRAMS	40.49		1.42	50.78		2.85
CO2 MASS GRAMS	1778.9		1955.0	1553.6		1895.6
NOX MASS GRAMS	2.64		.21	.17		.22
THC GRAMS/MI	1.27		.04	.97		.06
CO GRAMS/MI	11.31		.37	14.14		.74
CO2 GRAMS/MI	496.9		508.8	432.6		489.7
NOX GRAMS/MI	.74		.06	.05		.06
FUEL ECONOMY IN MPG	17.10	17.25	17.40	19.37	18.67	18.06
RUN TIME SECONDS	506.		868.	503.		868.
MEASURED DISTANCE MI	3.58	7.42	3.84	3.59	7.46	3.87
SCF, DRY	.978	.981	.983	.980	.982	.983
DFC, WET (DRY)		.918(.910)			.924(.916)	
TOT VOL (SCM) / SAM BLR (SCM)		196.5/ .00			195.4/ .00	

COMPOSITE RESULTS

TEST NUMBER		7
BAROMETER	MM HG	738.6
HUMIDITY	G/KG	5.5
TEMPERATURE	DEG C	25.0

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	485.4	(479.8)
FUEL ECONOMY	MPG	17.83	(18.03)
HYDROCARBONS (THC)	G/MI	.55	(.56)
CARBON MONOXIDE	G/MI	6.43	(6.52)
OXIDES OF NITROGEN	G/MI	.19	(.19)

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TEST NO. 7 RUN 2	VEHICLE NO.CP3	TEST WEIGHT 1701. KG(3750. LBS)
VEHICLE MODEL 91 S-10 PICK UP	DATE 3/28/91	ACTUAL ROAD LOAD 8.9 KW(11.9 HP)
ENGINE 4.3 L(262. CID) V-6	BAG CART NO. 2 / CVS NO. 2	GASOLINE EM-1198-F
TRANSMISSION L4	DYNO NO. 3	ODOMETER 32729. KM(20337. MILES)

BAROMETER 733.30 MM HG(28.87 IN HG) DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)
RELATIVE HUMIDITY 28. PCT ABS. HUMIDITY 5.4 GM/KG NOX HUMIDITY CORRECTION FACTOR .85

BAG RESULTS

BAG NUMBER	1		2	3		4
DESCRIPTION	COLD TRANSIENT		STABILIZED	HOT TRANSIENT		STABILIZED
BLOWER DIF P MM. H2O(IN. H2O)	1066.8 (42.0)		1066.8 (42.0)	1066.8 (42.0)		1066.8 (42.0)
BLOWER INLET P MM. H2O(IN. H2O)	1117.6 (44.0)		1117.6 (44.0)	1117.6 (44.0)		1117.6 (44.0)
BLOWER INLET TEMP. DEG. C(DEG. F)	42.8 (109.0)		40.0 (104.0)	41.1 (106.0)		39.4 (103.0)
BLOWER REVOLUTIONS	40441.		68910.	40127.		68766.
TOT FLOW STD. CU. METRES(SCF)	71.8 (2534.)		123.4 (4356.)	71.6 (2527.)		123.3 (4354.)
THC SAMPLE METER/RANGE/PPM	11.5/ 3/ 115.		7.2/ 2/ 7.	46.7/ 2/ 47.		7.1/ 2/ 7.
THC BCKGRD METER/RANGE/PPM	.6/ 3/ 6.		5.3/ 2/ 5.	5.6/ 2/ 6.		5.2/ 2/ 5.
CO SAMPLE METER/RANGE/PPM	58.7/ 1/ 519.		9.3/ 12/ 9.	63.6/ 14/ 294.		18.7/ 12/ 19.
CO BCKGRD METER/RANGE/PPM	.0/ 1/ 0.		.4/ 12/ 0.	.3/ 14/ 1.		.8/ 12/ 1.
CO2 SAMPLE METER/RANGE/PCT	75.4/ 1/1.3936		91.2/ 14/ .8965	66.2/ 1/1.2246		90.4/ 14/ .8768
CO2 BCKGRD METER/RANGE/PCT	2.5/ 1/ .0437		12.6/ 14/ .0422	2.7/ 1/ .0473		13.2/ 14/ .0446
NOX SAMPLE METER/RANGE/PPM	25.1/ 2/ 25.2		3.7/ 1/ 1.0	9.5/ 1/ 2.5		4.0/ 1/ 1.1
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .1		.3/ 1/ .1	.4/ 1/ .1		.3/ 1/ .1
DILUTION FACTOR	9.21		14.92	10.65		15.24
THC CONCENTRATION PPM	109.		2.	42.		2.
CO CONCENTRATION PPM	500.		9.	283.		17.
CO2 CONCENTRATION PCT	1.3546		.8571	1.1818		.8351
NOX CONCENTRATION PPM	25.1		.9	2.4		1.0
THC MASS GRAMS	4.52		.16	1.72		.16
CO MASS GRAMS	41.78		1.26	23.59		2.51
CO2 MASS GRAMS	1779.5		1935.7	1548.3		1885.4
NOX MASS GRAMS	2.93		.18	.28		.20
THC GRAMS/MI	1.25		.04	.47		.04
CO GRAMS/MI	11.51		.32	6.52		.64
CO2 GRAMS/MI	490.2		497.4	428.0		484.0
NOX GRAMS/MI	.81		.05	.08		.05
FUEL ECONOMY IN MPG	17.31	17.56	17.81	20.17	19.14	18.28
RUN TIME SECONDS	506.		868.	506.		868.
MEASURED DISTANCE MI	3.63	7.52	3.89	3.62	7.51	3.90
SCF, DRY	.978	.981	.983	.980	.982	.983
DFC, WET (DRY)		.918(.909)			.924(.916)	
TOT VOL (SCM) / SAM BLR (SCM)		195.1/ .00			194.9/ .00	

COMPOSITE RESULTS

TEST NUMBER		7
BAROMETER	MM HG	733.3
HUMIDITY	G/KG	5.4
TEMPERATURE	DEG C	23.9

		3-BAG	(4-BAG)
CARBON DIOXIDE	G/MI	476.8	(472.9)
FUEL ECONOMY	MPG	18.29	(18.43)
HYDROCARBONS (THC)	G/MI	.41	(.41)
CARBON MONOXIDE	G/MI	4.35	(4.44)
OXIDES OF NITROGEN	G/MI	.21	(.21)

Attachment 4

MANGANESE ANALYSIS – Mn BALANCE PROJECT

	Truck 1		Truck 2		Truck 3	
	Mn(g)	%	Mn(g)	%	Mn(g)	%
Total Mn Consumed in Gasoline	25.98	100.0	25.31	100.0	26.37	100.0
Mn From Exhaust						
Cyclone	0.83	3.2	0.70	2.8	0.77	2.9
HEPA Filter	6.10	23.5	6.16	24.3	6.59	25.0
Total Mn Exhausted	**6.93**	**26.7**	**6.86**	**27.1**	**7.36**	**27.9**
Mn From Internal Parts						
Pipes and Mufflers	5.63	21.7	4.79	18.9	5.42	20.6
Catalytic Converter	3.91	15.1	4.51	17.8	4.88	18.5
Motor Oil and Filter	2.96	11.4	2.93	11.6	3.30	12.5
Total Mn Found (Excl. Engine)	**19.43**	**74.8**	**19.09**	**75.4**	**20.96**	**79.5**
Additional Analysis on Truck 3						
Exhaust and Intake Manifold	--	--	--	--	2.17	8.2
Engine Deposits, Plugs, EGR	--	--	--	--	1.69	6.4
Total Mn Found (Incl. Above)	--	--	--	--	**24.82**	**94.1**

ATTACHMENT 1

Comments on the EPA/ORD Risk Assessment for MMT Use in Unleaded Gasoline

Clement International Corporation

Environmental and Health Science

Comments on the EPA/ORD Risk Assessment for MMT Use in Unleaded Gasoline

Chris Whipple, Ph.D.

Clement International Corporation

San Francisco, California

June 20, 1991

Comments on the EPA/ORD Risk Assessment
for MMT Use in Unleaded Gasoline

Executive Summary

In May 1990, Ethyl Corporation ("Ethyl") filed a waiver application with the U.S. Environmental Protection Agency ("EPA") under § 211(f) of the Clean Air Act for the use of the HiTEC 3000® Performance Additive ("MMT") in unleaded gasoline. As part of EPA's review of Ethyl's waiver application, EPA's Office of Research and Development ("ORD") completed a preliminary health risk and exposure assessment for use of MMT entitled, "Comments on the Use of Methylcyclopentadienyl Manganese Tricarbonyl in Unleaded Gasoline" ("ORD risk assessment"), November 1, 1990.

The purpose of the ensuing analysis is to refine the ORD risk assessment in light of new analyses and information that have become available since completion of the ORD analysis.

The principal conclusions of the review and update of the ORD risk assessment are as follows:

- The modifying factor of 3 used by ORD in the derivation of the manganese RfC is inappropriate. This means that the RfC is either too low, or that the ORD's characterization of uncertainty associated with the RfC is overly conservative.

- The order of magnitude range used to describe uncertainties in the RfC in risk characterization might be appropriate for an RfC derived from animal test results; it is overly conservative for an RfC based on a peer-reviewed human epidemiology study.

- Analyses and measurements made after completion of the ORD risk assessment indicate that manganese exposures to highly exposed groups would be significantly lower with MMT use than estimated by ORD. Exposures would be below the level of the RfC by a factor of 3 or more.

- Potential risks from MMT use were not considered in comparison to risks that would result if MMT is not used. Available data and analysis support the finding that MMT use would reduce the overall risks to health associated with the combustion of unleaded gasoline.

- This reassessment of the risks from the use of MMT in unleaded gasoline indicates that, when the modifying factor of 3 used in deriving the RfC is removed and when new exposure measurements and analyses are taken into account, high exposure subgroups (such as parking garage attendants or Los Angeles cab drivers) would experience manganese exposures at only about one tenth of the RfC. Because exposures at the RfC level are defined to be without appreciable risk of deleterious effect during a lifetime, it is possible to state definitively that the use of MMT in unleaded gasoline will not result in an appreciable health risk from inhalation exposures to manganese.

Introduction and Background

The EPA Office of Research and Development ("ORD") issued a November 1, 1990 report, "Comments on the Use of Methylcyclopentadienyl Manganese Tricarbonyl in Unleaded Gasoline" in response to a May 9, 1990 waiver application from Ethyl Corporation ("Ethyl"). The major conclusion of the ORD report was: "ORD concludes that, due to inadequacies in the exposure and health data bases, it is not possible to state definitively whether a significant health risk from inhalation exposure to manganese will, (or will not) occur with usage of MMT."

This paper reviews the data, analysis, and risk characterization of the ORD risk assessment in light of analyses and data that were not available when the ORD analysis was made. Since the ORD report was issued, a number of analyses and measurements have been made, especially concerning exposures to manganese that would result from MMT use. Many of these analyses were reported at a Manganese/MMT Conference and Workshop, sponsored by EPA, in Research Triangle Park, North Carolina on March 12-15, 1991, and are described in detail in the following attachments:

- Attachment 1 provides two letters to Ethyl regarding manganese concentrations in the Belgian factory in which the Roels et al study was conducted,

- Attachment 2 provides an exposure assessment for manganese based on the South Coast Risk and Exposure Assessment Model ("SCREAM"),

- Attachments 3 and 4 provide information relevant to reassessing manganese exposures based on individual data for exposures to lead, the only other metallic fuel additive that has been widely used in the U.S.,

- Attachment 5 provides data on manganese exposures in Toronto, Canada, where MMT is used in unleaded gasoline at a concentration up to two times higher than that sought by Ethyl for use in the U.S., and

- Attachment 6 provides a net risk analysis of MMT use.

Scope and Approach

The ORD assessment indicates that MMT itself does not appear to pose significant health or environmental risks, nor do exposures to manganese at the average levels that would result from MMT use. The major issue of concern to EPA, expressed in the ORD report, is with exposure of the most highly exposed portions of the population to manganese in the form of Mn_3O_4.

This report provides comments and analysis on the main issue raised in the ORD analysis: whether the use of MMT in unleaded gasoline would lead to significant health risks to highly exposed populations. The reassessment of the potential for significant risk is based on the following elements:

(1) an assessment of conservatism in the RfC,

(2) a more refined analysis of exposure,

(3) a net risk analysis for MMT use that provides a comparison of potential risks from the use of unleaded gasoline containing MMT versus the risks from the use of conventional unleaded gasoline, and

(4) a revised risk characterization based on the above items.

The Inhalation Reference Concentration ("RfC")

-- Derivation of the RfC

The basis of the EPA manganese RfC is as follows: The basic EPA reference study (Roels et al, 1987) found a LOAEL (lowest observable adverse effects level) of 970 $\mu g/m^3$; this was converted to a LOAEL-HEC (LOAEL-human equivalent concentration) of 340 $\mu g/m^3$ based on a conversion from an 8 hour occupational exposure duration to a 24 hour exposure.

To convert the LOAEL-HEC into an RfC, three uncertainty factors and one modifying factor were applied. An uncertainty factor of 10 was used to account for the fact that the reference exposure was a LOAEL rather than a NOAEL. A second uncertainty factor of 10 was applied to account for sensitive populations. A third uncertainty factor of 3 was applied to account for the fact that occupational effects were observed at less than a full lifetime exposure. In addition, a study-specific modifying factor of 3 was used to account for the possibility that individuals in the facility may have been exposed to increasing concentrations of manganese during the exposure period; such an increase, if it occurred, would imply that average exposures over the period were less than the measured value of 970 $\mu g/m^3$.

These uncertainty and modifying factors result in a combined factor of 900, which, when applied to the LOAEL-HEC of 340 $\mu g/m^3$, gives a value of 0.378 $\mu g/m^3$. EPA rounded this value off to an RfC of 0.4 $\mu g/m^3$.

Recent communications indicate that the modifying factor of 3 is inappropriate. Letters have been received by Ethyl from Dr. Robert Lauwerys, a coauthor of the Roels paper used by EPA to set the RfC and the Agency for Toxic Substances and Disease Registry ("ATSDR") of the U.S. Public Health Service to set a Minimal Risk Level ("MRL"), and from F. Delloye and M. Fautsch of Sedema (Sedema operates the facility in which the Roels study was conducted). These letters indicate that the plant was not operated in a manner that would have led to increasing exposures to manganese over time, as the factor of 3, included as a modifying factor in the RfC, suggests. Copies of these letters are provided as Attachment 1; they indicate that the increase in production at this factory was obtained by increasing the number of production units and number of workers operating them, and that it is incorrect to assume that exposures to manganese for individual workers increased over time.[1]

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[1]The ORD document cites two other studies (Iregren, 1990; Chandra et al, 1981) that indicate LOAEL-HECs around 100 $\mu g/m^3$. The ORD report described these studies as deficient in ways that precluded their use as principal studies on which the RfC could be based, but ORD notes that with appropriate uncertainty factors, these reports would have given similar RfCs to that derived from the Roels study.

The major deficiencies in the Iregren study cited in the RfC document is that no dose-response relation was observed and that the sample size was small; the Chandra study involved welders with no assessment of exposures other than from manganese. The status of the Chandra et al 1981 paper in terms of its overall contribution to the manganese-health literature appears to be minor; the paper was not given significant

-- Comparative Degree of Conservatism

Some insight into the relative degree of conservatism in the EPA RfC can be observed by comparing exposure standards for manganese established by other health organizations. The EPA RfC of 0.4 $\mu g/m^3$ is the lowest recommended limit for manganese exposure set by any health agency. For example, ATSDR has proposed a chronic inhalation MRL[2] of 2 $\mu g/m^3$, based on the same study (Roels et al, 1987) as

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attention in the EPA 1984 HAD for manganese; in fact the HAD described studies of effects on the central nervous system below 1 mg/m^3 as equivocal or negative. In the Roels paper on which the RfC is based, the authors note "Clinical signs of chronic Mn intoxication have rarely been reported at exposure levels below 5 mg/m^3 [Saric et al, 1977; Chandra et al, 1981; Tanaka and Lieben, 1969; Sabnis et al, 1966]."

A reasonable question to ask is whether ORD would have cited these studies if their results had not supported the derivation of an RfC consistent with that based on Roels, given that the deficiencies in these two studies were sufficiently serious to preclude their use by EPA in the RfC derivation. A process of citing studies while admitting that they have significant deficiencies seems inappropriate. Similarly, it would be inappropriate for EPA to ignore or discount the evidence provided here that the modifying factor of 3 used in deriving the RfC is not justified, based on the existence of the deficient Iregren and Chandra studies.

[2]ATSDR defines an MRL as "An estimate of daily human exposure to a chemical that is likely to be without an appreciable risk of deleterious effects (noncancerous) over a specified duration of exposure." The ORD defines an RfC as

> "An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effect during a lifetime. The inhalation reference dose is for continuous inhalation exposures and is approximately expressed in units of mg/m^3. It may be expressed as mg/kg/day, in order to compare with oral RfD units, utilizing specified conversion assumptions."

was the EPA RfC. The World Health Organization recommended air quality guideline (annual average) is 1 $\mu g/m^3$. According to the ATSDR manganese document, ambient standards have been set by several states, including annual ambient standards of 24 $\mu g/m^3$ in Pennsylvania and 119 $\mu g/m^3$ in Vermont.

Recommended manganese exposure limits for the workplace are higher, typically by a factor of around 1,000. The OSHA permissible exposure limit time-weighted average is 1 mg/m^3, the World Health Organization recommended limit for workplace air is 0.3 mg/m^3, and the American Conference of Governmental Industrial Hygienists recommended level is 5 mg/m^3. In a paper cited in the ORD report (Iregren, 1990), it is noted that the Swedish standard for an 8-hour workday is 2.5 mg/m^3 and that in "most other countries" the 8-hour standard is 5 mg/m^3.

In summary, the EPA RfC for manganese is too stringent by at least a factor of 3, based on the usual methods through which RfCs are derived. Had the EPA RfC been set without the additional factor of 3, i.e., at about 1 $\mu g/m^3$, it would have been consistent with the most stringent standards that have been set by other health organizations in the United States and around the world.

Note that the phrase "without appreciable risk of deleterious effect(s)" is used to describe the risk associated with an MRL or RfC in both definitions.

Manganese Exposure Assessment

Much detailed information regarding exposure assessment for manganese is included in the attachments to this analysis (see Attachments 2 through 5). The results of these new manganese exposure assessments are consistent in finding that peak exposures to manganese from MMT use as proposed by Ethyl would be far lower than was estimated in ORD's preliminary risk assessment. A short summary of the findings of these new manganese exposure assessments is provided below:

- Attachment 2 -- Gerald E. Anderson of Systems Applications International (SAI) analyzed manganese exposures in the Los Angeles metropolitan area through the use of SCREAM, a model developed by SAI for the South Coast Air Quality Management District. SCREAM has the capability to calculate exposures to various age-occupation groups based on the amount of time spent in specific micro-environments.

- Attachment 3 -- Ralph L. Roberson of SAI estimated the distribution of manganese exposures (i.e., the ratio of extreme to average exposures) based on the distribution observed for lead exposures. This observed distribution for lead is used in place of the exposure distribution, based on CO, used by ORD in its risk assessment.

- Attachment 4 -- This analysis by Gerard D. Pfeiffer, Donald R. Lynam, and Ben F. Fort of Ethyl estimates ambient urban manganese concentrations and individual exposures to manganese, based on concentrations and exposures to lead measured when all gasoline contained lead.

- Attachment 5 -- Data for manganese exposures to urban office workers and for manganese concentrations in a parking garage and motor courtyard in Toronto, Canada are provided. MMT is used in unleaded gasoline in Canada, at up to twice the concentration as Ethyl is proposing for use in the United States.

There is comparatively good agreement between the ORD analysis and other analyses regarding average exposures that would result from MMT use. It is for peak exposures that the analyses disagree.

The ORD estimate is that average national ambient exposure would be 0.04 $\mu g/m^3$ from background and 0.05P $\mu g/m^3$ from MMT use, where P is the fraction of manganese emitted. The average value for manganese emissions observed in emission testing conducted by EPA in August-September, 1990 (i.e., for P) was 12% of the amount used, although this factor is quite variable depending on driving cycle. For a manganese emission factor of 30% or less, the average exposure would be 0.055 $\mu g/m^3$ or less. It is clear that the average exposure is well below the RfC for any emission factor.

For average exposures to urban populations (in contrast to the national average estimate above, that includes exposures to both rural and urban populations), there is also good agreement between the ORD analysis and other analyses for typical exposures. The ORD analysis and SCREAM both predict that average exposures to urban office workers would be 0.04 $\mu g/m^3$ background plus 0.17P $\mu g/m^3$, where P is the manganese emission factor as before. For emission factors less than 30%, this analysis indicates that total exposure (background plus automobile sources) would be less than 0.09 $\mu g/m^3$. While the ORD and SCREAM estimates are comparable, the SCREAM estimates are for Los Angeles, while the ORD estimates refer to average urban conditions for U.S. cities in general. Because Los Angeles is a worst case urban area where auto emission exposures are concerned, this indicates that ORD's average exposure estimates are, if anything, conservatively high.

The ORD analysis, based on the high variability observed for CO exposure, indicated that for 30% manganese emissions, a million people would be exposed at or above the RfC level. The revised estimate in Attachment 3, based on exposure data for lead, finds peak exposures at only about one third the level estimated by ORD. The Azar data for lead, collected many years ago when all gasoline contained lead, is particularly relevant to the assessment of exposures to highly exposed groups, because lead and manganese can be expected to behave similarly in the environment. The Azar data include measurements of ambient air concentrations of lead in four U.S. cities (Philadelphia, Los Angeles, Starke, Florida, and Barksdale, Wisconsin), and measurements of lead exposures to Los Angeles and Philadelphia cab drivers and Los Angeles office workers. A discussion of the Azar data is provided in Attachment 3, along with a revised exposure analysis based on the ORD method and the Azar data.

Even this revised estimate, however, apparently overestimates exposure by a significant degree. Attachment 4, in which data for exposures to lead are used to estimate manganese exposures that would occur with MMT use, predicts significantly lower exposures. Measurements of lead exposures can be used to estimate exposures that would occur with MMT use, when adjustments are made to correct for the different concentrations of lead and manganese in gasoline and for background exposures to manganese. This analysis found that, based on the ratio of lead in gasoline to the proposed level of manganese in unleaded gasoline and including manganese background, urban ambient concentrations of manganese would be about 0.05 $\mu g/m^3$ for most cities, and around 0.07 $\mu g/m^3$ for Los Angeles. The predicted exposure of Los Angeles cab drivers to manganese is 0.11 $\mu g/m^3$.

Additional confirmation of these low exposure estimates (low in comparison to the estimate in the ORD risk assessment) is provided by manganese exposures measured in Toronto, Canada (see Attachment 5). Toronto was chosen because MMT is used in unleaded gasoline in Canada. These data indicate the apparently conservative nature of the modeled results. Average exposures measured for Toronto office workers were 0.013 $\mu g/m^3$, with a standard deviation of 0.009 $\mu g/m^3$. These measured exposures are significantly lower than estimates for background exposures alone; this may reflect a bias in where background is measured (i.e., that urban background measurements are taken in areas of high pollutant concentration).

In addition to the individual office worker exposure measurements, manganese concentrations were measured in a Toronto urban parking garage and in a covered motor courtyard. The highest measured concentration, taken in the center of a parking garage, was 0.41 $\mu g/m^3$. At this concentration, the average exposure to a parking garage attendant would be on the order of 0.11 $\mu g/m^3$ (assuming 40 hours per week exposure in a parking garage and the remaining time at the 0.013 $\mu g/m^3$ observed for urban office workers), a concentration that is only slightly over one fourth of the RfC.

In summary, the Toronto data find typical urban exposures to be less than 0.02 $\mu g/m^3$. The analysis described in Attachment 4, based on measured exposures to lead, suggest that exposures would be on the order of 0.1 $\mu g/m^3$ for Los Angeles cab drivers and below 0.07 $\mu g/m^3$ for most urban residents. The Attachment 3 analysis, in which the variability observed in lead exposures was used to predict peak manganese exposure, results in peak manganese exposure estimates of around 0.15 $\mu g/m^3$ for an emissions factor of 30%. The SCREAM analysis described in Attachment 2 predicts peak exposures to various age-occupation groups in Los Angeles to be less than 0.11 $\mu g/m^3$, based on a 12% emission factor. Adjusted for a 30% emission factor, SCREAM would predict peak exposures to be less than 0.2 $\mu g/m^3$.

It is noteworthy that the lowest estimates of manganese exposure come from the analyses most directly tied to direct measurement of exposure in the environment, that is, to the Toronto measurements of manganese and the measured concentrations and exposures to lead. The modeled results, including SCREAM and the revision of the ORD analysis based on lead distributions, give somewhat higher estimates. Taken in total, these exposure analyses indicate that few, if any, individuals are likely to experience manganese exposures at levels approaching the RfC.

Net Risk Analysis

Because measured emissions from autos using MMT are lower in carcinogens than emissions from similar cars using fuel of equal octane without MMT, one can calculate the net cancer risk reduction from MMT use. Such an analysis was conducted and presented at the Raleigh workshop (Attachment 6). This analysis also considered beneficial effects of MMT in reducing emissions of CO and NO_x, as well as the potential significance of a small increase in particulate emissions with MMT use. It concluded:

> This analysis indicates that a car run on unleaded gasoline with MMT has a less harmful mix of emissions than does a comparable car run on unleaded gasoline of equivalent octane. Whether one compares these two cases based on annual emissions in the U.S. or on the basis of potential exposures in high-concentration micro-environments, the analysis of net risk indicates that MMT use in unleaded gasoline would result in a net public health benefit.

Risks from carcinogen exposures were calculated at average exposure levels and at exposures to auto emissions at concentrations so high that the manganese RfC would be reached. It should be noted that actual exposures at the manganese RfC level are unlikely to occur; the point is to compare exposures from MMT fuel with non-MMT fuel for someone in a micro-environment with high auto emissions. The two tables below, taken from Attachment 6, summarize the results of the net risk analysis. The calculations behind this analysis assumed a 20% manganese emission factor for average exposures and sufficient emissions to produce exposure to manganese at the level of the RfC (0.4 $\mu g/m^3$) for high exposures. In these tables, individual risk refers to the plausible upper bound estimate of the lifetime chance of cancer incidence based on standard methods of analysis used by EPA's Carcinogen Assessment Group.

Table 1 indicates that, following standard EPA methods for calculating cancer risk, MMT use would reduce annual cancer incidence due to carcinogenic auto emissions by up to 48 cases. Table 2 indicates that those in a high exposure group would be subject to carcinogenic auto emission exposures with lifetime cancer risks calculated to be up to 4 per 10,000 higher than would be the case with MMT use.

Table 1

Carcinogen Risks

Average Exposure Risks with and without MMT

	Without MMT		With MMT	
	Indiv risk	Cancer cases/yr	Indiv risk	Cancer cases/yr
Formaldehyde	7.02E-6	26.1	5.98E-6	22.2
Benzene	2.16E-5	80.2	1.62E-5	60.1
Acetaldehyde	3.41E-7	1.3	2.76E-7	1.0
1,3 Butadiene	4.2 E-5	156.0	3.56E-5	132.1
Sum of 4 HCs	7.09E-5	263.5	5.80E-5	215.5

Risk Characterization

Risk characterization refers to the act of putting the various pieces of analysis together to reach an overall judgment. The major pieces in this case are the information on health

Table 2

Carcinogen Risks

High Exposure Environment with and without MMT

	Without MMT		With MMT	
	Indiv risk	Cancer cases/yr per 10^6	Indiv risk	Cancer cases/yr per 10^6
Formaldehyde	2.31E-4	3.3	1.97E-4	2.8
Benzene	7.10E-4	10.1	5.33E-4	7.6
Acetaldehyde	1.12E-5	0.16	9.07E-6	0.13
1,3 Butadiene	1.38E-3	19.7	1.17E-3	16.7
Sum of 4 HCs	2.33E-3	33.4	1.90E-3	27.3

risks (in this case, the RfC and the information on which it is based) and the exposure assessment. But a risk characterization is not meant to be a mindless, automated process; it also includes judgments about the quality of the data and nature and sources of uncertainty. Additional considerations, such as those raised in the net risk analysis, are appropriately considered in risk characterization.

-- The ORD Risk Characterization

The ORD risk characterization (pages 11 through 15 of the ORD risk assessment), starts by characterizing the ORD exposure assessment. It reports that typical inhalation doses to urban office workers are estimated to be in the range from 0.8 to 3 μg/day, [assuming 20 m^3 of air is inhaled per day, a range of 0.8 to 3 μg/day corresponds to a concentration of 0.04 to 0.15 $\mu g/m^3$]. In comparison, the inhalation RfC of 0.4 $\mu g/m^3$ corresponds to an exposure of 8 μg/day. However, ORD notes that: "In some cases (less than 1 percent of the population), these exposures may be up to an order of magnitude higher." For 30% manganese emissions, ORD estimates a range of exposure "from 1 to 8 μg/day or greater," and further notes that "uncertainty around both the estimated exposure and the RfC is approximately an order of magnitude."

ORD's Figure 1, found on page 13 of their report, graphically illustrates the RfC and exposure estimates with uncertainty bounds applied. In this figure, the uncertainty boundaries for exposure to manganese range from 0.25 to 25 μg/day, and the RfC is represented as an order of magnitude wide range, in which the 8 μg/day RfC value is the geometric mean. This means that the range of the RfC extends from 2.5 to 25 μg/day. With this broad uncertainty range, ORD's RfC overlaps the range for ORD's estimated exposure to manganese.

-- Uncertainties in the RfC

While uncertainty bands around RfCs have not historically been used, the subject of RfC uncertainty bands and criteria by which they are specified is defined in the recent EPA ORD report <u>Interim Methods for Development of Inhalation Reference Concentrations, Review Draft, August 1990.</u> This document defines a Reference Concentration (RfC) as:

"An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime. The inhalation reference dose is for continuous inhalation exposures and is appropriately expressed in units of mg/m^3. It may be expressed as mg/kg/day, in order to compare with oral RfD units, utilizing specified conversion assumptions."

Under Section 4.3, Criteria for Specifying Level of Confidence, the report states:

"The qualitative and quantitative nature of this process results in estimated benchmark values such as the RfC associated with varying degrees of confidence that can be described as high, medium, and low. The confidence ascribed to the result is a function of both the quality of an individual study and the completeness of the supporting data base."

Much of the EPA guidance document's discussion of criteria for specifying confidence levels deals with various types of evidence from animal experiments. A section on Human Data begins by noting that, "Utilization of human data avoids the necessity of extrapolating from animals to humans, thereby decreasing uncertainty in the risk assessment." Appendix D, Criteria for Assessing the Quality of Individual Epidemiological Studies, notes that the study should be reported in the peer-reviewed literature, and lists 6 additional criteria for evaluation.

These quotes indicate that EPA's draft envisions that confidence in the RfC should be characterized as high, medium, or low, where "low" would result in an order of magnitude uncertainty band around the RfC. For cases such as manganese, where the RfC is based on a peer-reviewed human epidemiology study, it is inappropriate to characterize the confidence in the RfC as low; low seems appropriate for RfCs and RfDs developed from animal data. At the Raleigh Manganese/MMT Conference, the confidence level in the RfC was described as medium. For these reasons, an order of magnitude uncertainty band around the RfC is larger than needed, based on EPA's guidance document.

The explanation of the basis for the use of this uncertainty band in the risk characterization section contradicts ORD's position in the response to NIEHS comments on pages 54-55 of the ORD report. The NIEHS comments refer to "potential subclinical effects to the nervous system thought to represent a loss of reserve function" and to issues such as the identification of sensitive subpopulations, to variability in individual sensitivity, and to the potential for irreversible or long-term effects. EPA's response to these comments was:

> "ORD believes that all of these issues are being addressed in the form of the oral RfD or in the inhalation RfC for Mn. The RfC methodology requires review of the data base, selection of the critical paper for RfC derivation, and application of uncertainty factors and modifying factors to account for sensitive subpopulations and uncertainties in the data base."

In direct contradiction to this response to the NIEHS comments, the risk characterization section of the ORD analysis explains that uncertainty factors and modifying factors were applied to account for sensitive populations and uncertainties in the data base, and then describes concerns with depletion of reserve function and the severity and reversibility of potential health effects as additional uncertainties that must be accounted for again by applying an order of magnitude uncertainty factor in risk characterization.

While the risk from manganese inhalation may be uncertain, these uncertainties were considered in the development of the RfC from the LOAEL-HEC. The RfC represents a concentration at which there is high confidence, after taking uncertainties into account, that exposure is safe. This is particularly true for the manganese RfC given, as noted above, the inappropriate use of an additional modifying factor of 3 in deriving the RfC. To include uncertainties on top of those included into the RfC derivation, as is done in this risk characterization, represents double counting.

-- Comment on the Exposure Range

Based on the results described in the Manganese Exposure Assessment section above and in Attachments 2-5, peak exposures to manganese with MMT use were shown to be likely to fall into the range of 0.2 to 2.9 μg/day. [To convert from μg/day to $\mu g/m^3$, divide by 20.] These estimates are based on the conservative assumption that there is 100% market penetration by MMT.

The upper end of this range, 2.9 μg/day (see Attachment 3), is based on applying the variability observed in lead exposures to estimate peak manganese exposures. The lower end of the estimated exposure range is supported by actual measurements of lead exposures in a highly exposed group (e.g., Los Angeles cab drivers) and of a high exposure micro-environment (a Toronto parking garage). The average measured exposure in Toronto office workers was 0.26 μg/day, with a standard deviation of

0.18 μg/day. On this basis, the upper end of the ORD exposure range (25 μg/day) is 137 standard deviations above the average urban office worker exposure measured in Toronto. The RfC (8 μg/day) is 43 standard deviations above the Toronto average urban office worker exposure. As noted above, the estimated exposure to a parking garage worker, based on the highest measured concentration and assuming 40 hours exposure per week, is about 2.2 μg/day.

The SCREAM analysis estimated that incremental exposures (i.e., those above background) for urban populations would range up to 1.2 μg/day for a 12% manganese emission factor. For a 30% emission factor, these values would range up to 2.5 times larger, or a maximum of 3 μg/day. Assuming background exposures of 0.8 μg/day, total exposures to even the most highly exposed age and occupation groups in Los Angeles would still be less than one half the level of the RfC.

-- Net Risk Considerations

Net risks were not analyzed by ORD. Aside from a comment that use of MMT could reduce exposures to benzene, no estimate of possible health benefits was made. The key aspect of the net risk analysis provided here and summarized above is that, for whatever highly exposed population group considered, exposures to manganese can be expected to scale proportionally with reductions in exposures to carcinogenic hydrocarbons and to CO and NO_x. Particulate exposures would be increased with MMT use, but by a small fraction of the ambient standard for particulates, even in the case of the most highly exposed groups. From the perspective of any potential member of a high exposure group at any projected exposure level, the potential benefits from MMT use increase in proportion to exposure to auto emissions.

The data developed in support of the Waiver Application indicate that a car run on unleaded gasoline with MMT has a less harmful mix of emissions than does a comparable car run on unleaded gasoline of equivalent octane. Both one the basis of annual emissions in the U.S. and on the basis of potential exposures in high-exposure micro-environments, the analysis of net risk is similar. These data and the accompanying analysis show that MMT use in unleaded gasoline would result in a net public health benefit.

Summary of Findings

- New information indicates that the modifying factor of 3 used in the derivation of the manganese RfC is inappropriate. Due to a lack of data on manganese concentrations or on plant characteristics at the Belgian factory that was the basis for the RfC, EPA considered the possibility that exposures increased over time because plant output increased and therefore included the modifying factor. Recent correspondence from Dr Lauwerys, one of the authors of the RfC reference study, and from personnel at the Sedema facility in which the RfC reference study was conducted, indicate that concentrations were not increasing with time.

- The ORD document applies an order of magnitude range to account for uncertainties in the RfC in its risk characterization. Using this added uncertainty factor for the manganese RfC, when the RfC is based on a peer-reviewed human epidemiology study, is overly conservative.

- Regarding ORD's assessment of manganese exposure, the analyses described here indicate that peak exposures with MMT use are significantly lower than previously estimated by ORD, and lower than the RfC by at least a factor of 2, and more likely by a greater margin. The most reliable information on what exposures would be with MMT use, i.e., the actual exposures measured in Toronto, were considerably lower than exposures predicted by ORD and SCREAM, and well below the level of the RfC.

- The potential risks from MMT use were not considered in comparison to the risks that will result from not using MMT. When a comparative perspective is adopted, the evidence clearly supports the view that MMT use is beneficial on an environmental, health, and economic basis. This is true for both an average individual and for individuals in a high exposure group. Existing data and analyses indicate that MMT use would provide a positive net benefit to society as a whole and to those who experience peak exposures to automobile emissions.

In summary, this reassessment of the risks from the use of MMT in unleaded gasoline indicates that, when the modifying factor of 3 used in deriving the RfC is removed and when new exposure measurements and analyses are taken into account, high exposure subgroups (such as parking garage attendants or Los Angeles cab drivers) would experience manganese exposures at about one tenth of the RfC. Because exposures at the RfC level are "likely to be without appreciable risk of deleterious effects during a lifetime," (from the definition of an RfC in the EPA ORD August 1990 Review Draft), it is possible to state definitively that the use of MMT in unleaded gasoline will not result in an appreciable health risk from inhalation exposure to manganese.

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